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# **Science & Technology**

***CHINA: Energy***

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# Science & Technology

## China: Energy

JPRS-CEN-92-003

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30 March 1992

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### Nation's Energy Achievements in 1991 Recapped

926B0050B Guangzhou NANFANG RIBAO in Chinese  
6 Jan 92 p 4

[Text] China holds on to first place among the world's leading coal producers as last year's (1991) total national output of 1.08 billion metric tons kept pace with that of the previous year.

Electric power production reached a new level as China's total output last year (1991) rose above 670 billion kWh, 9 percent above the previous year, and it is growing at a rate higher than the average output during the Seventh 5-Year Plan. The total newly installed capacity for the entire year was 11 million kW, placing China second in the world in terms of newly installed power capacity.

Petroleum and natural gas production reached their highest levels in history, 139.6 million metric tons of oil and 15.2 billion cubic meters of natural gas. The old oil fields in the east maintained high output, while prospecting and development in the west continued to set records.

Nuclear power output broke new ground on the mainland, as the Chinese-designed and constructed Qinshan nuclear power plant successfully joined the grid last year on 15 December, bringing China into the nuclear power age for the first time. Meanwhile, construction of the Daya Bay nuclear power plant is moving ahead rapidly, and the first unit will go into operation next year.

The success of the energy industry in the first year of the Eighth 5-Year Plan was a great boost to the overall development of China's economy, and provides the foundation and the experience needed for the future development of China's energy industry.

### Development of Petroleum Industry Reviewed

40100026A Hong Kong LIAOWANG OVERSEAS  
EDITION in Chinese No 6-7, 17 Feb 92 pp 33-34

[Article by Li Yongzeng [2621 3057 1073]: "Secure the East, Advance to the West—Development Trend of China's Petroleum Industry as Seen From 1991"]

[Excerpt] The year 1991 was another year of steady development in China's petroleum industry. There was no big fluctuation, and there was increase amid stable output. Since 1986 when annual petroleum output reached 130 million tonnes, for six consecutive years China's annual petroleum output has remained in the area of 130 million to 140 million tonnes. For the petroleum industry, which is a highly risky exploration, this is really something.

### Cautious and Conscientious; Increase Amid Stable Output

In the past year, based on the state's basic principle of "securing the east and developing the west," and with the spirit of great care and precision, the petroleum industry strove to strengthen exploration of major oil fields in east China, securing the output situation; at the same time, it made efforts to expedite the development and construction of new oil zones in west China, making great achievements in both regions.

—Petroleum and gas productions in the whole country witnessed steady increases. In 1991, the country produced a total of 139.76 million tonnes of crude oil, and 15.4 billion cubic meters of natural gas. Of this, crude oil produced on land was 137.37 million tonnes, 370,000 tonnes more than the state's plan; the output of natural gas was 14.9 billion cubic meters, 200 million cubic meters more than the state's plan.

—The situation of development of oil fields improved. Throughout the year, newly built crude oil production capacity was 14.91 million tonnes, surpassing the planned quota by 24.3 percent. Compared with the previous year, the daily volume of water injection in the whole country increased from 1.9 million cubic meters to 2.04 million cubic meters, and daily output of liquid increased from 1.66 million tonnes to 1.78 million tonnes, thus, the two matched each other basically and grew simultaneously. The average rising speed of comprehensive water content in the oil fields throughout the country decreased by 0.6 percent, and the comprehensive diminishing rate of oil wells in the country decreased by 0.37 percentage point. All these signify that the level of development of oil fields was upgraded.

—Oil and gas prospecting scored great results. Old zones were deepened, new zones were developed, and oil and gas reserves increased simultaneously, while the search for oil and gas continuously expanded. It is expected that for the whole year, verified geologic reserves of petroleum would surpass the original plan by 10 percent, and geologic reserves of natural gas would surpass the original plan by 270 percent, setting the highest record in more than 40 years.

—Scientific and technological development scored a number of results. The petroleum industry received a total of 11 state awards for scientific and technological advancement and inventions, and 142 ministerial-level awards for scientific and technological achievements; it made earnest efforts to promote 32 complete sets of advanced technologies, and 80 individual advanced technologies. According to the preliminary estimates by 14 oil fields, calculable economic returns amounting to a total of 1.27 billion yuan were attained. The major scientific and technological research projects such as the horizontal well drilling technology; the polymer-injecting tertiary recovery technology; and the technology for prospecting and exploring breaches and extremely shallow seas have produced results in the course of production. In addition, the technology for handling three-dimensional earthquakes and for meticulously handling data, for drilling an oriented cluster of wells, for reforming low-penetrating oil deposits, and the heat technology for extracting thick oil were further improved and promoted. Technological reform and renewal of facilities also went at a faster pace.

—Making a step forward in cooperation with foreign countries. Last year, we signed three agreements on foreign loans and two prospecting contracts with foreign petroleum companies and financial groups, importing technologies, equipment, and special instruments amounting to \$1.1 billion. Among which, the contract for prospecting

the Dongting Hu Basin has been carried out for a year, and the contract on prospecting the Poyang Hu Basin will be officially carried out beginning this year, while the agreement on cooperation in research in the south has also been carried out for 6 months. At the same time, the petroleum system developed its own strong points, explored the international market through various channels, and signed some contracts on important projects. In particular, the Chinese fire-extinguishing team took part in extinguishing the well fires in Kuwait, and was praised by the Kuwaiti side and various foreign counterparts; it established a good reputation and image in the international market.

China's petroleum industry started in the western part of the country. Since 1960 when the Daqing oil field began development, the center of the petroleum industry shifted to the coastal areas in east China. At present, the major oil fields in east China accounted for more than 90 percent of the country's output of 140 million tonnes of oil. In 1991, the top three oil fields—Daqing, Shengli, and Liaohe—produced an annual output of 55.62 million tonnes, 33.55 million tonnes, and 13.7 million tonnes of crude oil respectively, and the total output surpassed 100 million tonnes, accounting for 75 percent of the country's total output. Whether the east can be secured, and particularly whether the three major oil fields can be developed steadily, has a bearing on the overall national economy.

According to the information provided by the department concerned, at present many oil fields in east China have already extracted 50 percent of the extractable reserves, and the average water content surpasses 80 percent. In particular, in the 3 years from 1988 to 1990, the annual increase in extractable reserves did not match the annual extracted volume in the past, and the remaining extractable reserves decreased year after year, to the extent that it was more difficult for east China to maintain a stable output. Zhongyuan oil field, which had an output ranking it fifth in the whole country last year, extracted oil from its first well in 1975, and began large-scale development in 1979; its highest annual output was 7 million tonnes in 1988, thereafter, its output decreased year after year, from 6.9 million tonnes in 1989, to 6.3 million tonnes in 1990, and to 6.1 million tonnes in 1991. The most typical case is Huabei oil field, which currently has an output ranking it sixth in the country. It began development in 1975, set a record of annual output of 17.33 million tonnes in 1979, making a big contribution to allowing China's annual crude oil output to jump to 100 million tonnes, however, due to its unique geological conditions, the Huabei oil field declined as rapidly as it rose, and in 1983 its output dropped to 10.55 million tonnes; in 1987, 7.59 million tonnes; in 1989, 5.48 million tonnes; and in 1991, 5 million tonnes. In addition, the Dagang oil field, which has the seventh position in the country, had the highest annual output of 4.5 million tonnes in 1975, and its output decreased year after year, to 3.8 million tonnes in 1991.

In order to make up for the reduced outputs in these oil fields, other fields have to expedite development and use reserves. The petroleum system is like a stretched bow and,

in order to support rapid national economic growth, it works cautiously, conscientiously, and diligently throughout the year. Making a macroeconomic decision, the state promptly proposed the strategic arrangement of "securing the east and developing the west," and the petroleum industry began to allocate some strength to expedite prospecting and development of the west.

Fortunately, before the west produces any great result, the three major oil fields in the east can still maintain stable outputs at this moment, and even have some slight increases, though very small. The Daqing oil field, which has been explored for more than 30 years, had an annual output reaching 50 million tonnes in 1976. Since then, its output has been stable for 16 years up to now, and for seven years its output steadily reached 55 million tonnes. Supported by a complete set of modern scientific and technological measures, the underground situation at the oil field is good, a balance between injection and extraction is maintained, the stratigraphic pressure is stable, the natural diminishing rate and the comprehensive diminishing rate are under control, the result of exploration of outer oil fields becomes better every year, and all these have laid a foundation for continuing the stable output. At present, the underground situation at Shengli is characterized by the natural diminishing rate, the comprehensive diminishing rate, and the annual increasing rate of water content have dropped respectively, while the stratigraphic pressure steadily increased, and this has laid a good foundation for this year's stable output. The Liaohe oil field, which has good staying power, began development in 1970, reached 10 million tonnes in 1986, and 13 million tonnes in 1988; in the past few years it was still in the stage of steady growth, and according to plan, it will reach an annual output of 15 million tonnes in 1995.

The sustained stable output among the old oil fields in the east has won time for the prospecting and development of the west. People certainly hope that the east can maintain stable output, the longer the better. The work in the west is affected by the climate and environment and cannot proceed too fast. First, the oil deposits are very deep, generally surpassing 5,000 meters, and one test well requires six months' drilling; second, the area is vast and is sparsely populated, and geological prospecting is rough and crude, and a great deal of work is required. Since 1989, when an integrated effort was organized, more than 3 billion yuan have been invested in it. In 1991, Tarim Basin produced 500,000 tonnes of crude oil, and Turpan-Hami Basin produced 200,000 tonnes. At present, development of the west has turned in the direction of foreign loans, and the crude oil it produces is sold at the international market price in order to earn foreign exchange, which is used to feed the petroleum industry and stimulate development.

According to information, in 1991, prospecting work in the three major basins in west China proceeded smoothly. The geologic reserve of oil verified in the whole year was 1.6 times the volume detected in the previous year, and a number of favorable oil-deposit structures were also found, further proving that the west is the realistic area for relaying the resources strategy in developing China's oil industry.

In Tarim Basin, five oil fields—Lunnan [6544 0589], Donghetong [2639 3109 1048], Jilake [0679 2139 0344], Sangtamu [2718 1044 2606], and Liberation Canal East—have been verified; in the Tazhong and Yingmaili areas, a number of high-yielding oil and gas wells have been opened. It is estimated that after finishing testing a number of major wells this year, the resources prescribed in the Eighth 5-Year Plan for crude oil production can be obtained. Regional prospecting shows gratifying promise. Recently, Lunnan's well 59 found in a stratum in the Carboniferous system a high-yielding oil and gas current capable of producing 98 cubic meters of crude oil and 1.18 million cubic meters of gas daily. An estimate based on the currently available data shows that it is very likely a stratum containing large oil and gas deposits. Jinan's well 1 and Lunnan's well 46 also found in the sandrock in the Silurian system new strata bearing oil and gas. All these indicate that the Paleozoic strata south of the Lunnan areas are a favorable area for searching for oil, and that continuing expansion of prospecting work will yield a number of important results.

In Turpan-Hami Basin, the result of prospecting is much better than expected. At present, six oil fields have been discovered in the hilly crescent zone in Shanshan County, and the oil-bearing domains are expanding northeast and southwest. According to the currently available geological results and prospecting progress, it is expected that the building of output capacity in the Eighth 5-Year Plan period can be accomplished ahead of schedule.

In Junggar Basin, prospecting work extended from the border to the hinterland. At present, Cainan oil field has been discovered in the Wucaiwan district in the eastern part of the interior. The five test wells in the district have all found industrial oil currents, and some 40 square km of oil-bearing area have been under control. At the same time, in the Mosuowan district, which is in the center of the hinterland, a 30-meter thick oil-bearing layer has been found during drilling. These indicate that the Cainan-Mosuowan area of some 4,000 square km is a very favorable oil and gas concentration belt, with very good promise for prospecting. The Xinjiang Petroleum Management Bureau, which mainly oversees Karamay oil field in the northwestern part of the basin, steadily and rapidly increased oil output in the past 10 years or so, reaching 3 million tonnes in 1977, 4 million tonnes in 1982, 5 million tonnes in 1985, 6 million tonnes in 1988, and 7.02 million tonnes in 1991, becoming the fourth largest oil field in the country.

Natural gas prospecting in west China has also made exciting breakthroughs. In Sichuan's old gas field, a large potential gas-bearing structure has been discovered, and the area is more than 200 square km, with two new test wells containing high-yielding gas currents. In the eastern part of Qaidam Basin, the gas-bearing area of the gas field further expanded. In particular, in the Jingbian-Hengshan area in Shaanxi-Gansu-Ningxia Basin, China's largest gas field has been discovered. At present, we have controlled more than 3,200 square km, and finished drilling 31 test wells; along with the deepening of prospecting, the gas-bearing area is extending to the north, the west, and mainly the south.

The petroleum industry is a state pillar industry, and oil and gas fields are large or extraordinarily large enterprises. The state has already decided that during the Eighth 5-Year Plan the petroleum industry will continue to practice the contracting system. In order to continuously deepen reform in the course of carrying out the contract responsibility system, and to change the operational mechanism and improve economic returns, the State Council, after carrying out careful research for the whole year, has now agreed in principle to the petroleum industry's contracting plan for the later 4 years in the Eighth 5-Year Plan, and made clear some policies and measures. These signify that the reform of the petroleum industry will enter a new phase. [passage omitted]

### Three Gorges' Impact on Coal Exploitation, Power Generation and Transportation

926B0055a Beijing RENMIN RIBAO in Chinese  
26 Jan 92 p 2

[Text] The electricity generating benefits of the proposed Three Gorges project are great. It would be a 17.68-million-kilowatt facility, equivalent to seven large-scale, 2.4-million-kilowatt thermal power plants. It would be larger than Brazil's Itaipu hydroelectric station, currently the largest in the world (12.6 million kilowatts). It would generate 84 billion kilowatt hours of electricity per year, and the economic benefits would be equivalent to a coal mine that produces 40 to 50 million tons per year and two railroads 800 to 1,000 kilometers long. It would mainly supply electricity to the Central China Power Network (Hubei, Hunan, Henan, Jiangxi) and the Eastern Power Network (Shanghai, Zhejiang, Jiangsu, Anhui). These regions are quite developed agriculturally and industrially, and are the areas that are short on energy resources and where it is difficult to transport coal.

The Three Gorges project will require a total of 57 billion yuan in static investment (at 1990 prices). Construction would begin after 3 years of preparation, and after 9 years the first and second units would be generating electricity. Every year after that, four units (each unit producing 680,000 kilowatts) would go into operation. In the 15th year, construction would be complete. The hydroelectric stations that China has already built generally earn back the entire static investment 6 years after completion. With the Three Gorges project, the entire static investment will be earned back after only 2 years after completion. There are three reasons why its effectiveness will be greater than the other hydroelectric stations: First, the topography and geology of the dam area are good, and the large dam will be situated along the 8-kilometer stretch of dense granite cliff wall. The Three Gorges project's electricity generating capacity will be 6.5 times greater than Gezhouba, and the large dam will require only 2.5 times the construction work of Gezhouba. Second, the Chang Jiang has a large volume of water. Third, it is close to areas that will use the electricity.

If work begins next year, the Three Gorges project will be completed in the year 2010. By that time, the country's seven major power networks (Northeast, North, Northwest, East, Central, Southwest, and South) will be connected by

500,000-volt lines. With the Three Gorges project located in the center, controls in the inter-drainage valleys can be established to take full advantage of the different starting and ending dates of each region's rainy season. This will enable each region's hydroelectric stations to generate less electricity during the dry season, save more water, maintain power generation while the water is high and make full use of the water. According to estimates, the amount of additional power that the country's hydroelectric stations have to generate because of this is equivalent to about 3 to 5 million kilowatts.

Even though it is clear that the Three Gorges project will be effective in generating electricity, it is, after all, a huge project, and during the numerous discussions among electric power experts, there were some serious disagreements at first. Later, after research had been done on balancing all of the country's resources, particularly coal, electricity, and transportation issues in the central and eastern regions and the issue of employment for China's huge population, it was determined that the Three Gorges project had to be built, and that it should commence as soon as possible.

### 1.

Generally speaking, to develop the national economy, electric power must lead the way and be a foundation, and the rate of electric power development should be greater than the rate of growth in industrial and agricultural output value.

Looking from a historical standpoint, in the 14 years between 1952 and 1966, the entire country's industrial and agricultural output value increased at an average annual rate of 8.53 percent, while electric power output increased at an average annual rate of 18.9 percent. There was no shortage of electricity in 1966. During the 10-year Cultural Revolution, the average annual increase in electrical output fell to 9.43 percent and the industrial and agricultural output value increased at an average annual rate of 7.13 percent. In 1970, there began to be a shortage of electricity, and by 1975 the country had a shortage of 5 million kilowatts. From 1979 to 1986, because planning held back the rate of power development (the Sixth 5-Year Plan called for 3.8 percent average annual increase in power output), the annual rate of increase in power output fell to 7.3 percent. This was lower than the average annual growth in industrial and agricultural output value (10.1 percent), and caused the power shortage to become increasingly serious. In 1980, the electrical shortage was 10 million kilowatt hours, in 1985 it was 12 million kilowatt-hours and in 1986 it was 15 million kilowatt-hours. After that, leaders in the State Council asked for speedier installation of power generating equipment, which turned the situation around somewhat. In 1991 the power output was 8.9 percent greater than in 1990, and the gross national product increased by 7 percent (the statistics on industrial and agricultural output value have not yet been released). In early 1991 there was still a shortage of 1.9 million kilowatt-hours of electricity, and after the fourth quarter a phase of the administrative reorganization ended, and the Central, Eastern and other power networks began to have major shortages of electricity.

Based on the history of China's economy, electric power experts have formed this conclusion: The rate of electric power development cannot be lower than the rate of growth in industrial and agricultural output value, and must at least keep pace with the industrial and agricultural output value. The party's 12th Plenum set a goal of quadrupling industrial and agricultural output value in 20 years, and therefore electrical power would have to at least quadruple. In 1980 about 60 million kilowatt-hours of electrical generating equipment was installed nationwide, which would reach 240 million kilowatts by the year 2000. Based on the 1980 shortage of 10 million kilowatt-hours, according to the 240 million kilowatt-hour plan, by the year 2000 there would still be a shortage of 40 million kilowatt-hours. According to a forecast plan for the year 2015 that was drawn up in 1987, if the electricity shortage problem is to be solved, at least 290 million kilowatts must be reached by the year 2000, and an 8.8 percent annual rate of growth must be maintained.

The doubling of the nation's industrial and agricultural output value was already achieved in 1987. In October 1987 the party's 13th Plenum established the goal of quadrupling the GNP in 20 years. The goal became weightier, but in 1988 the target date for doubling the GNP was moved up 2 years. From now on, if the increase in the GNP is maintained at 6 percent, then the goal of doubling it again by the year 2000 can be achieved. Because statistical methods have changed, using the GNP to calculate the annual rate of growth yields a figure more than 2 percentage points lower than when the industrial and agricultural output value is used (for example, according to actual statistics for the 8 years from 1981 to 1988, the average annual growth in industrial and agricultural output value was 12.1 percent, and during the same period, the GNP increased at an average annual rate of 10.1 percent; according to actual statistics for the 5 years from 1986 to 1990, the average annual growth in industrial and agricultural output value was 11 percent, while during the same period the average annual increase in the GNP was 7.8 percent). Thus, from now on, if the planned average annual growth in the GNP is 6 percent, then the industrial and agricultural output value must increase at an average annual rate of 8 percent or slightly more, and not the 6.1 percent that some people have calculated. According to the model that the development of electrical power must at least keep pace with the growth in industrial and agricultural output value, the increase in electrical power must be maintained at 8 percent or higher.

After the year 2000, if the GNP is doubled again by the year 2015 (an average annual increase of 4.73 percent), then electric power must at least double, reaching 580 million kilowatts. By 1990, 130 million kilowatts of electrical generating equipment had been installed nationwide, and in the next 25 years, there must be 450 million kilowatts of installation. Nuclear power can produce only 30 million kilowatts at most, and coal-fired power is projected to produce 300 to 310 million kilowatts. An additional 900 million tons of coal would have to be burned—a very large amount. All things considered, we should strive to construct more hydroelectric facilities—at least 110 to 120 million kilowatts of hydroelectric capacity. But even if all of the conventional hydroelectric stations that produce 50,000

kilowatts or more in all of the eastern coastal provinces, in all of the central provinces (including the ones where the Three Gorges are located), those below the Yellow River's Longyang Gorge, those on Guizhou's Wu River and others were to all be developed, along with the Manwan, Xiaowan, Dachaoshan and Nuozhadu hydroelectric stations along Yunnan's Lancang River, only 94.62 million watts would be accumulated. As a result, the series of large-scale hydroelectric stations on the Dadu River and Yalong River still need to be developed, as well as the 10 to 15 million kilowatt pumped-storage hydroelectric stations nationwide. If the Three Gorges' 17.68 million kilowatts is not developed, it will be difficult to achieve the total capacity of 110 million kilowatts through the development of hydroelectricity.

2.

Can the method of lowering the rate of development of the national economy be used to solve the problem of insufficient electrical power? I believe that this is not feasible. Because a great number of people have already been born, when they turn 18, they must find work. According to population statistics, from 1986 to 1990, 132 million people turned 18, and in those five years, enterprises in villages and towns absorbed 95 million people and the urban floating population increased by 50 million people (a portion of those went into enterprises in villages and towns). From 1991 to 1995, 110 million people will turn 18; from 1996 to 2000, 95 million people; from 2001 to 2005, 100 million; from 2006 to 2010 there will be some decrease, but there will still be more than 89 million people turning 18. Calculating based on the average annual growth in urban and rural labor productivity for the 33 years from 1952 to 1988, and assuming that urban and rural laborers leave the labor force at age 60, then from 1991 to 1995, the industrial and agricultural output value must increase by 8.02 percent annually; from 1996 to 2000, by 7.24 percent annually; from 2001 to 2005, 7.21 percent annually; and from 2006 to 2010, 6.46 percent annually. If the calculation is based on the GNP, then the average annual growth must be 6.22, 5.45, 5.42 and 4.68 percent respectively. If the rate is lower than this, then tens of thousands of people will be unemployed, and this is unacceptable.

3.

China has a large population, which has a great demand for energy, and the need to balance our resources is becoming increasingly urgent. It is projected that in the year 2015 we will need about 2.2 billion tons of standard coal resources. At that point, crude oil (or natural gas) will have reached only 300 million tons at most, and if raw coal production reaches 2 billion tons per year, the two together will add up to an equivalent of 1.82 billion tons of standard coal. Nuclear power will reach 30 million kilowatts at most, equivalent to the electricity produced by about 48 million tons of standard coal; hydropower will reach 140 to 150 million kilowatts, equivalent to the annual production of electricity from about 130 to 167 million tons of standard-grade coal. Altogether, it would add up to 1.998 to 2.035 billion tons of standard coal, which would still leave a shortage of almost 200 million tons.

China relies mainly on coal for its energy resources, and the coal is primarily concentrated in the resource base of Shanxi, Shaanxi, Western Inner Mongolia, and Ningxia. After the year 2000, the coastal provinces, along with Jilin, Hubei, Hunan, Jiangxi, Sichuan and other provinces, will become increasingly dependent on coal supplied by the coal-producing base area. There are three ways to transport the resource from the base area, all of which are subject to huge limitations due to natural conditions.

First, transporting coal by railroad is limited by railroad construction and mountain passes. In 1990 rail capacity away from the base area was 221 million tons, and 221.8 million tons was actually transported (of which 175 million tons was coal). After the currently planned railroad construction is completed, it can reach 356 million tons in the year 2000 (including 300 million tons of coal), and in the year 2000 coal production in the base area will reach 540 to 600 million tons, with 350 to 400 million tons being shipped away. In 2015, the base area will produce more than 1 billion tons of coal, with 700 million tons being shipped away. According to materials from railroad planning departments, railroads constructed from the base area to Hebei and Henan are limited by mountain passes and can only reach 500 million tons or slightly more.

Second, building power plants in the coal-producing area to transmit electricity to the outside is a good way to save on transportation capacity. But generating electricity requires water, and that area has a shortage of water resources. According to the plan, in 2015 an additional 24 million kilowatts of coal-fired facilities will be constructed in the area, and 24 half-million-volt transmission lines will transmit the electricity to the Northeast, Beijing, Tianjin, Tangshan, Shandong and Henan. But as of now, more than half of them have not found water resources, and as a result, there has been no way to determine sites for the plants.

Third, using pipelines to transport 40 million tons of coal to the outside also requires solving the water resource problem.

The above analysis shows that in order to solve the electrical power shortage problem, hydroelectric power must be developed on a large scale at the same time as the development of coal-fired power and nuclear power. Construction of the Three Gorges project is absolutely necessary. If the Three Gorges Project is not constructed, and coal-fired power is substituted, at least 40 million more tons of coal will have to be transported, which far exceeds the transportation capacity of the railroads, and there are no more mountain passes over which to build railroads.

### Coal Firm Spells Out Export Goals

40100028 Beijing CHINA DAILY (Economics and Business) in English 3 Mar 92 p 3

[Article by staff reporter Chang Weimin]

[Text] China's coal mines look set to strengthen trade and economic cooperation with foreign countries.

Yesterday in Beijing, Hu Fuguo, president of the China National Coal Corporation (CNCC), announced his firm's plans on foreign trade and economic cooperation, saying bold steps will be taken.

Hu made the remarks at CNCC's annual conference. Hundreds of officials gathered to discuss the future.

CNCC, which exported some 20 million tons of coal last year, this year will widen the variety of its export products.

They aimed to maintain exports of raw coal at last year's level but exports of other coal products, including coke and coal tar, are to be increased.

In addition, exports of coal-mining machinery are planned to be increased by 20 percent against \$12.6 million worth sold last year, which was about twice the 1990 figure.

Hu said his firm wants to absorb more investment and technology from overseas by adopting new trading methods including compensation and barter trade, jointly running mines and technology exchanges.

This year, CNCC will expand its foreign trade and economic cooperation by starting more business with neighboring nations.

CNCC, which turned out 369 million tons of the country's total coal output of 1.08 billion tons last year, exported 20.12 million tons of coal, an 11 percent increase over the State plan.

Foreign exchange earnings that year were \$760 million, up 30 percent from State plan.

The firm exported 17.72 million tons of coal in 1990, which earned \$650 million.

Hu announced his firm's plan on development for this year as well as the coming years, saying strengthening coal processing to turn out more value-added products is the only way for rapid development in the future.

He said that during the 1992-95 period, the firm will invest 1 billion yuan (\$180 million) in 112 projects to strengthen its coal cleaning and grading capacity.

When the projects are finished, it will be possible to clean 50 million tons of coal a year and grade 11 million tons.

By then, the proportion of cleaned coal will be increased to 58 percent of the total from the present 37 percent, and the proportion of classified coal to 47 percent.

According to the plan, 33 coal cleaning plants will be expanded and 35 projects on coal cleaning technical renovation carried out.

The projects should produce profits of 760 million yuan (\$139 million) a year. Hu said the investment in the projects could be recouped within one year and four months on average.

Last year, the firm put five coal cleaning plants into operation, which can wash 14.4 million tons of coal a year.

By using 7.9 billion yuan (\$1.45 billion) as investment for capital construction, the firm also put 16 mines into production, which can turn out 21.4 million tons of coal a year.

### **Big Progress Made in Substituting Coal for Oil**

*926B0055b Lanzhou GANSU RIBAO in Chinese  
11 Jan 92 p 3*

[Text] China's effort to carry out the substitution of coal for oil has achieved great results in the past 10 years. Over 10 years, fuel oil consumption was reduced by a total of 87.7 million tons, which made positive contributions to improving our country's petroleum consumption structure to the stable development of the national economy. On 6 January, the premier of the State Council, Li Peng, wrote an inscription for the 10th anniversary of the establishment of the State Council's office of substituting coal for oil: "Prudent use of petroleum resources; continuous implementation of substituting coal for oil."

It is understood that in the early 1980's China's annual fuel oil consumption reached a peak of more than 40 million tons, which accounted for 40 percent of the entire country's annual petroleum production. To prudently use our petroleum resources, the country arranged for more than 800 million yuan in start-up funds for substituting coal for oil, and using a self-generating development approach, accumulated funds for substituting coal for oil.

In the past 10 years, total fuel oil consumption has been reduced by 87.7 million tons, a decrease of 15.74 million tons per year; 32.2 billion yuan in funds has been accumulated for substituting coal for oil. Using these funds, 20.27 million kilowatts of electrical generating facilities and 47.17 million tons of coal-mining facilities were constructed, and a series of railroads, ports and advanced processing equipment for oil refineries and electric power facilities was built. The Huaneng Group, which has the goal of developing the energy resources industry, was also formed. At the same time, advanced technology to substitute liquefied coal for oil, desulphurize exhaust from electrical plants and more has been introduced and developed so that China, with its abundant coal resources, will be in the world's forefront in the area of coal use technology. At a news conference called today, Tu Zhuming, the deputy director of the State Councils' office on special funding for substituting coal for oil, indicated that in the next 10 years, China will reduce oil consumption by an additional 10 million tons.



**Remote Sensing Technology Successful in  
Locating Underground Oil and Gas Deposits**

926B0065A Beijing ZHONGGUO KEXUE BAO  
[CHINESE SCIENCE NEWS] in Chinese 21 Jan 92  
p 1

[Article by reporter Chen Xiechuan [7115 0588 1557]:  
"Remote Sensing Technology Displays Its Skills, Under-  
ground Oil and Gas Resources Apparent in One  
Glance"]

[Text] The "Oil and Gas Resource Remote Sensing Direct  
Prospecting Technology Research Project" jointly sup-  
ported by the Chinese Academy of Sciences Remote Sensing  
Institute and the China Petroleum and Natural Gas Pros-  
pecting Corporation's Petroleum Exploration and Develop-  
ment Science Academy and involving the efforts of nearly  
100 S&T personnel in 16 research units over 4 years has  
been examined and accepted by experts.

The experts stated that oil and gas deposits buried at  
considerable depths underground are in a state of rela-  
tively dynamic equilibrium. There are substantial pres-  
sures within them and enormous pressure differentials  
relative to the surface. This causes the hydrocarbon mate-  
rials and associated compounds in the oil and gas pools to  
migrate to the surface along the direction of the pressure  
gradient. Research in foreign countries has confirmed that  
small molecule hydrocarbon gases can migrate and pene-  
trate capping strata 300 meters thick in 14 days and that it  
takes just 140 days for hydrocarbons in oil and gas pools at  
a depth of 3,000 meters to migrate to the surface. On the  
basis of this theory, they successfully established a set of oil  
and gas resource remote sensing exploration and evalua-  
tion technology models based on determinations of the  
hydrocarbons in oil and gas deposits and successfully used  
aerial shortwave infrared spectral scanning technology to  
achieve the objective of direct exploration of favorable  
areas for the accumulation of oil and gas resources. This  
research achievement has been used in methods testing in  
Xinjiang's Junggar Basin and in trial production in the  
Tarim Basin. The rate of conformity with exploratory  
drilling confirmation or partial confirmation was greater

than 60 percent. This opens up an economical, quick, and  
effective new route for remote sensing direct exploration  
for oil and gas resources.

The Examination and Acceptance Committee directed by  
Academic Department member Liu Guangding [0491 0342  
7844] feels that oil and gas resource remote sensing direct  
exploration technology is a vanguard topic in remote  
sensing applied research at the present time. This research  
also uses oil and gas deposit hydrocarbon microleakage  
migration theory as a foundation along with infrared  
absorption waveband remote sensing imaging technology  
for direct exploration for oil and gas resources. It is at  
vanguard levels internationally and has broad applications  
prospects and extension value.

**GPS Satellite Used To Map Xingyi Field in  
Guizhou**

926B0050A Guiyang GUIZHOU RIBAO in Chinese  
8 Dec 91 p 1

[Article by Xiong Hesheng [3574 0735 3932]]

[Text] Using a GPS satellite for geo-positioning to make a  
survey map of Xingyi oil field on a scale of 1:5000, survey  
teams of the Guizhou Oil Field Prospecting Corporation,  
and engineers, technicians, students, and teachers of Wuhan  
Mapping S&T University, all working together in the field,  
were successful in attaining a digital resolution down to 5  
centimeters. They accomplished this high-quality mission at  
a savings of 176,800 yuan.

In 1987 China imported and began to use the GPS  
satellite position fixing technology, an international  
high technology of mid-1980's vintage. Last year, the  
Guizhou Oil Field Prospecting Corporation undertook the  
Xingyi oil field mapping task. Senior engineer, Kou  
Changyou [1379 7022 2589], of the survey team  
responsible for the task, and Professor Wang Kunjie  
[3769 2492 0267] of Wuhan Mapping S&T University,  
conducted the survey in the mountainous area [of  
Guizhou]. They decided to use a composite transmis-  
sion layout, and skillfully applied the GPS technology  
to the mountainous area (800 square kilometers). The  
two parties worked well together, and in only 20 days  
mapped the entire area. This survey technology is 2 to  
3 times as effective as normal survey methods, and  
experts believe this accomplishment represents an  
advanced-level national research achievement.

**Situation Report on Tianshengqiao II**

926B0037A Beijing SHUILI FADIAN [WATER POWER] in Chinese No 10, 12 Oct 91 pp 14-16

[Article by Duan Xiangji [3008 4382 1015] of the People's Armed Police First Hydropower Brigade: "Brief Introduction to the Tianshengqiao Second Cascade Hydropower Station Project"]

[Text] The Tianshengqiao Second Cascade (dam index) Hydropower Station is located on the Nanpan Jiang, the boundary river between Anlong County in Guizhou Province and Longlin County in the Guangxi Zhuang Autonomous Region, 385 km from Guiyang City and 587 km from Nanning City. The river basin above the dam site covers an area of 50,194 km<sup>2</sup> and the perennial average amount of available water is 19.4 billion m<sup>3</sup>. The design peak flood flow rate (1 percent) at the dam site is 13,500 m<sup>3</sup>/s. The design impoundment water level in the reservoir is 645 m, corresponding to a reservoir capacity of 26 million m<sup>3</sup>. The power station has a design head of 176 m and uses long tunnels to divert water for power generation. The initial installed generating capacity will be 880MW (four 220MW units), with guaranteed output of 199MW and average yearly power output of 4.92 billion kWh. The eventual scale of installed generating capacity will be 1,320MW.

The main structures of the power station include three parts, the primary facility, the water diversion system, and the plant buildings. The primary facility is composed of non-overflow dams on the left and right banks, an overflow dam, silt flushing locks, power station water diversion system intake, and so on. Its configuration is shown in the illustration [not reproduced]. The top of the dam is 470 m long, the elevation of the top of the dam is 658.7 m, and the maximum dam height is 58.7 m. There are a total of nine outlets in the riverbed spillway dam, each outlet having a net width of 12 m. The elevation of the top of the weir is 631.3 m and it has planar steel gates. The total maximum discharge rate is 18,275 m<sup>3</sup>/s and the single-width flow rate is 132.3 m<sup>3</sup>/s/m. There are a total of three silt flushing gates, each outlet being 3 m wide and 7.82 m tall. Two of the outlets are bottom outlets and are used to flush away riverbed silt. The other outlet is connected to a gallery in front of the intake opening and runs laterally through the dam. It flushes away the silt in front of the intakes of the power generation tunnels. The three outlets have a maximum flow rate of 486 m<sup>3</sup>/s. The dam section of the intakes of the water diversion system is 70 m long and has a total of three openings. There is a gate pier in the middle of each opening. The gate openings are 6 m wide and 9 m tall and there is an open diversion channel 180 m long ahead of the intake.

The diversion system is composed of a dam-type intake, diversion tunnels, differential-type surge shafts, high-pressure penstock, and so on. There are a total of three diversion tunnels, each 9,766.21 m long (including the intakes and reinforced concrete open pipe sections connecting the intakes with the face of the tunnels that are 221.3

m long). The axes of the three tunnels run parallel and the axial lines are spaced 40 m (limestone area) to 50 m (sandy shale area) apart.

The power house building has a total length of 166.6 m and includes a main generator room 119.2 m long, 21.5 m wide, and 58.6 m tall. The generators are spaced 19 m apart, the installed elevation of the generators is 434.5 m, the elevation of the water turbine level is 438.0 m, and the elevation of the power generation level is 447.5 m. The auxiliary plant buildings are divided into six levels and are located next to the upstream and downstream walls of the power house. The main transformer and 500 kV switching stations are upstream from the plant building in a terraced arrangement. The switching station is a closed-type combination electrical device.

The main part of the project required excavation of 5.469 million m<sup>3</sup> of rock and soil, excavation of 3,099,300 m<sup>3</sup> of rock tunnels, pouring of 1.579 million m<sup>3</sup> of concrete and sprayed concrete, 320,000 m of solid grouting, 269,800 m<sup>3</sup> of refill grouting, and 25,800 m of curtain grouting.

The People's Armed Police First Hydropower Brigade entered Tianshengqiao in March 1982 and joined the Ninth Hydropower Engineering Bureau to begin preparing for construction. The formal start of construction on the main part of the project was at the end of 1984. A construction program using three-phase diversion during the dry season was adopted for the primary facility. The open diversion channels were built to the right of dam section 18 (not including dam section 18) and to the left of dam section 22 (not including dam section 22) during the first phase. This provided flow capacity conditions that corresponded to the diversion standards. The right bank at the head of the reservoir and the high slope on the right bank at the dam site were put in order to improve communication and transportation conditions for construction of the primary part. The flow passed through the original riverbed during the dry season. In the second phase, the upstream and downstream flow-through weir and silt flushing gates (dam section 18), dam section 17 to their left, nine riverbed spillway channels and upstream and downstream protection aprons were built during the second phase. The flow passed through the open channel on the right bank during the dry season. During the third phase, the silt-trap sill was built at the intake of the open diversion canal, a coarse grate trash screen was installed on top of the sill, the dam-type intake, flush gallery, and three reinforced concrete open diversion pipes were completed, and the flood relief channel gates were completed, as was installation of the intake gates and other metallic structures and installation and debugging of all of the headstock gear, giving the proper operational and utilization conditions during power generation. The flow passed through the flushing gates and over the overflow weir during the dry season.

At the end of 1985, construction got underway in succession on all work faces for the diversion tunnels. The method used to build the three branch tunnels during construction was that the No 1 and No 3 branch tunnel work faces were drilled, blasted, and excavated while two 10.8 m diameter tunneling machines were used in the No 2 branch tunnel for

full cross-section tunneling upstream from the main No 1 and No 2 tunnels. Most of the work faces in the No 3 branch tunnel were sandy shale while all the work faces in the No 1 and No 2 branch tunnels were limestone. The main tunnel between the two branch tunnels was about 7.2 km long and it was the key tunnel section that controlled the power generation and construction schedule. The No 1 primary tunnel was opened up in August 1991.

Advanced technical measures were employed in construction: 1) Rolled concrete dam construction technology was successfully used for the intake dam; 2) A 10.8 m diameter full cross-section tunneling machine was used to excavate the tunnels; 3) Relatively advanced comprehensive engineering measures were employed to inhibit landslips and control the high slopes; 4) Pumps were used to transport the mixed sand and concrete and the sprayed protective mixed sand and concrete; 5) Relatively advanced landslide dynamic monitoring systems were used.

### Overview of Construction at Wanan Key Project

926B0037B Beijing SHUILI FADIAN [WATER POWER] in Chinese No 10, 12 Oct 91 pp 41-43

[Article by Jiang Zhicheng [3068 1807 2052] of the People's Armed Police First Hydropower Brigade: "Brief Introduction to the Wanan Hydropower Station Project"]

[Text]

### I. Project Overview and Benefits

#### A. Project overview

Wanan Hydropower Station was one of the state's key energy resource construction projects during the Seventh 5-Year Plan. It is located in Wanan County in Jiangxi Province and is the first large power station built on the trunk of the Gan Jiang. The power station controls a river basin covering an area of 36,900 km<sup>2</sup> with a perennial average runoff of 29.9 billion m<sup>3</sup>, equal to 44 percent of the yearly runoff on the Gan Jiang, and it has a total reservoir capacity of 2.216 billion m<sup>3</sup> and an effective reservoir capacity of 1.019 billion m<sup>3</sup>. The ultimate installed generating capacity of the power station will be 500MW, with a total of five generators, each with a unit capacity of 100MW (four are to be installed in the initial phase). It will have guaranteed output of 60.4MW and generate 151.6 million kWh of power annually. After the upstream and downstream cascades are completed and go into combined operation, its guaranteed output will increase to 101MW and yearly power output may reach 193.5 million kWh.

The key facility for the Wanan Hydropower Station project is composed of a concrete gravity dam (a dam crest overflow dam, bottom outlet spillway dam, non-overflow dams on the left and right banks, a power house, ship locks, earthen dam, irrigation canal heads on the left and right banks, and so on. The configuration of the key facility is shown in the illustration [not reproduced]. The dam crest has a total length of 1,104 m, the elevation of the dam crest is 104 m, and the maximum height of the dam is 58 m. The plant building is a riverbed type. The effective dimensions of the

ship locks are 175 X 14 X 2.5 m (length X width X water depth) and the maximum head is 32.3 m. This is the largest head for single-stage ship locks in China at present.

The amount of engineering involved in the main part of the Wanan Hydropower Station project is excavation of 3.55 million m<sup>3</sup> of rock and earth, 2.50 million m<sup>3</sup> of rock and earth fill, 1.68 million m<sup>3</sup> of concrete, 46,320 t of steel bars and steel materials, 28,654 m of solid grouting, 15,805 m of screen grouting, and 13,000 t of metallic structure installation. The budgetary estimate set for the project at the time of the "five determinations" in 1984 was 784.63 million yuan. At the end of 1990, the "Wanan Hydropower Station Supplementary Budgetary Estimate" examined by the Central Water Conservancy and Hydropower Planning and Design Academy was 1.388 billion yuan (not including the supplementary portion for dealing with reservoir inundation).

### B. Project benefits

The river basin controlled by Wanan Hydropower Station covers a large area and there is abundant precipitation within the basin. There are significant comprehensive utilization benefits since it has power generation, flood prevention, water-borne shipping, irrigation, breeding, and other comprehensive benefits. It has major significance for eliminating poverty in the old revolutionary base area region of Jiangxi and for developing industrial and agricultural production and promoting the four modernizations drive.

1. Power generation. At present, the three North Jiangxi, Central Jiangxi, and South Jiangxi grids in Jiangxi Province have not been interconnected. Wanan Hydropower Station is the largest hydropower station in Jiangxi Province. When completed, it can serve as the key power station for grid integration and become the primary power source for frequency regulation and peak regulation in the Jiangxi Grid. It will play a significant role in alleviating Jiangxi's electric power shortage and improving the quality of power supplies.

2. Flood prevention. After Wanan Hydropower Station is completed, when operating at the flood prevention high water level of 100 m, it can provide 1 billion m<sup>3</sup> in flood prevention reservoir capacity, and it can raise the flood prevention standard for the large dikes in eastern Jiangxi (protecting the vast "Ji-Tai [Ji'an-Taihe] basin" and "Gan-Fu [Ganzhou-Fuzhou] plain" regions below the dam site) from once in 15 years to once in 50 years and reduce the once in 30 to 50 year flood water level in the "Ji-Tai basin" by 0.3 to 1 m. The maximum peak drainoff rate is 6,500 m<sup>3</sup>/s.

3. Water-borne shipping. The Gan Jiang cuts through Jiangxi from south to north and is a major water-borne shipping artery for Jiangxi Province. Its yearly freight volume accounts for more than one-half of total water-borne shipping in Jiangxi. Because no improvements have been made in the river channel for a long time, the shipping channel is unstable and the depth is insufficient for transport during the dry season, which has affected the development of water-borne shipping. After the hydropower station

is completed, it will submerge 18 upstream shoals and reservoir regulation can increase the flow rate downstream during the dry season, increase the shipping depth by 0.19 m during the dry season, and improve shipping conditions on the Gan Jiang. Wanan Hydropower Station is fitted with two 500 t grade ship locks and has a yearly handling capacity of 1.3 to 1.5 million t.

4. Irrigation. The diversion flow rate at the head of the canals on the left and right banks is 4 m<sup>3</sup>/s and 5 m<sup>3</sup>/s, respectively, which can irrigate 300,000 mu of farmland via natural flow, increase the drought resistance capacity of the "Ji-Tai basin" and "Gan-Fu plain", and guarantee the production of commodity grain.

5. Breeding. After the reservoir is completed, the breeding area could reach 150,000 mu.

### III. Construction Overview

#### A. Overall configuration of construction

Prefabricated concrete plant buildings, mixing systems, and cooling systems are located on the left and right banks. A steel pipe plant and primary equipment as well as metal storage yards along with water supply, ventilation, and power supply systems are located on the left and right banks 1.5 km downstream. However, the sand and rock production systems are concentrated on the right bank 7.5 km downstream and residential areas and central warehouses are located along the river. The concrete mixing systems and finished sand and rock product warehouses are located downstream from the dam site on the left bank.

Communication with the outside at the construction site depends mainly on highways. There is a grade 2 highway running to Nanchang (318 km) to the north. There is a transfer station and branch line at the Anfu Railroad Station between Fenyi and Jinggangshan 170 km from the construction site. The large axles, rotors, transformers, and other large components for the generators will be shipped by water to the construction site from Nanchang, so communication is relatively convenient.

#### B. Construction auxiliary enterprises

1. Sand and rock material production system. Wanan Hydropower Station will use nearly 1.7 million m<sup>3</sup> of concrete. The aggregate is natural stone from the Gan Jiang. The main storage yards are at Yunzhou, Luotang, and Baijia and the total reserves will be 4.38 million m<sup>3</sup> of conglomerate with a sand content of 66 to 70 percent, and an additional 1.8 million m<sup>3</sup> of supplementary sand will be needed. However, because the Gan Jiang is a grade 6 shipping channel and the shipping channel is narrow during the dry season and has a shipping depth of less than 1 m, ships cannot reach Luotang and Baijia, so the excavation will mainly be concentrated at the Yunzhou materials yard and the vast excavation region. Three sand dredges with a power of 150 m<sup>3</sup>/h and excavation depth of 9 m as well as one with a power of 120 m<sup>3</sup>/h and excavation depth of 6 m will be used. They will tow conveyor sand barges and transport the sand and rock to the shore from two piers using  $b = 1,000$  mm belt conveyors. Effective use will be made of the dry season and expanded excavation depth to

increase output and crushed rock will be used to supplement the small rock and large rock along with other methods. This will satisfy the requirements of concrete production. The aggregate will be loaded by loaders or conveyors onto trucks for transport 7 km to the finished materials warehouses for the mixing systems on the left and right banks at the dam site.

2. Mixing systems. A 3 X 1,600 mixing building and two 2 X 5,000 and 3 X 1,600 mixing buildings will be placed 300 m from the axis of the dam at an elevation of 80 m on the left and right banks, respectively. Their monthly production capacities will be, respectively, 30,000 and 80,000 m<sup>3</sup>/month. A 500 t cement tank and 450 m<sup>3</sup> bagged cement warehouse will be placed on the left bank. Three 500 t cement tanks will be placed on the right bank along with a 1,200 m<sup>3</sup> cement warehouse and 200 m<sup>3</sup> powdered coal and lime warehouse that can store 2,000 t. The cement and powdered coal and lime will be transported by air pressure to the mixing building for storage.

3. Cooling system. The 2 X 5,000 mixing building for the mixing system on the right bank will be configured with one cooling building having a cooling capacity of 12.3 GJ/h (2.94 million kilocalories/h). It can produce cooled cement with an outlet temperature of 14 to 17° C and 2° C cooled water, with production capacities of, respectively, 90 and 230 m<sup>3</sup>/h.

#### C. Construction diversion and floodwater transit.

The main high water period on the Gan Jiang is from April to June. July to September is a moderate water period and October to the next March is the dry season. The Gan Jiang river channel is open to shipping year-round. A two-phase diversion program to first enclose the right of the riverbed was adopted. A diversion wall in the middle of dam section 16 and the upper vertical section and lower vertical section of the vertical cofferdam are used to form a vertical cofferdam that is used during both phases. The first-phase cofferdam on the right bank protects the construction of the power house and bottom outlet dam sections below while at the same time the ship locks on the terrace on the right bank pass ships on the left side of the shipping channel. The diversion standard is a year-round frequency of 5 percent (flow rate 15,500 m<sup>3</sup>/s). In the second phase, the left of the riverbed is enclosed and the 10 bottom outlets built during the first phase and the second phase water transit cofferdam on the left bank are used for diversion to pour the overflow dam on the left bank. The ship locks are also temporarily used for ship passage and the cofferdam is used to divert water for power generation.

Arbitrary fill from ship lock excavation was used for the first phase cofferdam and steel plates and pillars along with cement and water glass grouting were used for leakage prevention. An RCC overflow cofferdam was used for the lateral cofferdam upstream on the left bank and there is a lateral downstream rock and earth overflow cofferdam with a steel bar network protective facing. Cement and clay grouting was used on part for leakage prevention, and the leakage prevention results were relatively ideal.

The first-phase cofferdam diversion standard was high and only a 7,000 m<sup>3</sup>/s flood occurred from 1985 to 1989 during the construction period, so construction went rather smoothly. The water transit cofferdam on the left bank diverted floods with a frequency of 5 percent from October to the following March (flow rate 7,100 m<sup>3</sup>/s). The base pit required rock excavation, pouring of concrete, foundation processing, metallic structure installation, and many other operations, so the project's form prior to high water and the removal of large construction equipment were the prerequisites for safe floodwater transit. For this reason, we strengthened reservoir dispatching so that we could enable safe construction of the left base pit and take into consideration the use of generators to generate electricity and the use of the ship channel temporarily to allow the passage of ships, with rather good results.

#### D. Main project construction

1. Rock and soil excavation. Wanan Hydropower Station involved the excavation of 3.55 million m<sup>3</sup> of rock and earth including excavation of 1.2 million m<sup>3</sup> of rock. Some of the capping strata in the riverbed at the dam site were composed of conglomeratic coarse sand, fine sand, and small pebbles with a thickness generally ranging from 1 to 4 m. The trench on the right side of the riverbed was 17.5 m deep. The high overflowed shoals on the right bank were composed of clay and sandy pebbles (the lower part was 0.5 to 4.5 m thick) and limy yellow earth (4 to 9 m thick) with a total thickness of about 5 to 10 m. The first terrace on the right bank was composed of clay and conglomerate with a total thickness of 9 to 14 m. The foundation of the structures was mainly fine-grained quartz sandstone and purple-colored powdered sandstone in thick strata with interbeds of sandy shale. The rock strata were tilted downstream at an inclination of generally about 20°. There were several small-scale faults in the dam site region, the larger faults including f<sub>33</sub>, f<sub>160</sub>, f<sub>18</sub>, and others. Structural cracks were developed, most of them being steep angle shear cracks and most having a NNE strike. Rock weathering was relatively developed. Because of the effects of lithology, structures, and weathering, there were rather large differences in the physical and mechanical properties of the rock in the dam site region. The wet compressive strength of the micrograined new rock was usually 80 to 120 MPa while the wet compressive strength of the weak weathered rock was usually 30 to 90 MPa. The maximum depth of excavation at the site of the plant buildings was 25 m and the highest slope was 35 m. In addition, a one-time blasting technique to remove the protective strata was invented (it received a second-place S&T progress award from the former Ministry of Water Resources and Electric Power). During a 9-month period in 1985, a total of 189,000 m<sup>3</sup> capping strata and 378,000 m<sup>3</sup> of rock were excavated in the area of the plant buildings and the maximum monthly strength of excavation was 80,000 m<sup>3</sup>. The quality conformed to design requirements and excavation of the concrete construction work faces was completed 7 months ahead of schedule in the "five determinations" plan.

2. Foundation processing. Because the geological conditions in the primary generator section and diffusion section of the

main plant building were rather good, the amount of work involved in solid grouting was reduced. Because of the effects of the fault zones and bedrock fracture development, low-toxicity propyl solidified chemical grouting was used for the screen grouting on the ship locks and dam sections 26 and 25. Regarding the largest fault at Wanan, f<sub>33</sub>, it was originally thought that the fault was a torsional type on a relatively large scale and a rather complex occurrence with a fragmentation zone of 1 to 3 m and an influence zone of 1 to 2.5 m. It was 2 to 5 m wide at outcrops and foundation stress requirements could be met by plugging it with concrete to a depth of 5 to 7 m. During actual excavation, it was discovered that the fault was rather small in scale and only required refilling with 1,000 m<sup>3</sup> of concrete.

3. Concrete engineering. The concrete was poured in two phases. Horizontal transport depended mainly on three heavy-light 762 locomotives and a refitted vertical concrete tank car. Because the mixing system equipment was at an elevation of 80 m and most of the base pit bedrock was at an elevation of 65 m, drop measures were used to transport the concrete ahead of the ship locks, plant buildings, and bottom outlets. A 10t/30t full-gate machine and 10t/30t small high overhead door machine produced by Sanmen Gorge Hydraulics Plant were used for the vertical transport. The maximum monthly pouring rate per unit was 8,000 m<sup>3</sup>/month, the maximum monthly pouring rate during the first phase was 43,000 m<sup>3</sup>/month, and the maximum annual pouring rate was 320,000 m<sup>3</sup>/year. Large amounts of double-mixing as well as slip forms, pull forms, LW, and HW water stopping materials were used in producing the concrete for Wanan Hydropower Station, which saved considerable cement and reduced project costs as well as improved the quality of concrete construction. There was a 100 percent rate of conformance with specifications for the concrete engineering and the superior rate was 80 to 85 percent.

#### Accelerating Development of the Lancang Jiang Hydropower Base

926B0048A Beijing SHULI FADIAN [WATER POWER] in Chinese No 12, 12 Dec 91 pp 6-9

[Article by Wang Xinmao [3769 0207 5399] of the Water Conservancy and Hydropower Planning and Design Academy]

[Text] The Lancang Jiang is one of 12 hydropower bases in China, and since the 3d Plenary Session of the 11th CPC Central Committee, the development of its mainstream has gone well; the Manwan hydropower station on the middle reaches is at a peak of construction activity, and the preliminary work on all of the cascade projects is progressing energetically. In recent years, the writer has kept in touch with the development and planning of the Lancang Jiang mainstream hydropower base, and has observed, first hand, several dam sites, and examined the feasibility study report for the Dazhaoshan hydropower station and the dam selection report for the Xiaowan hydropower station. Through his work he has gained a deep appreciation for the exceptional wealth of hydropower resources of the Lancang Jiang

mainstream, its superior topographical and geological conditions, its steady and plentiful volumes of water, the negligible reservoir inundation, and the comprehensive advantages its use offers; it is a veritable "gold mine" of hydroelectric resources. In recent years, Yunnan Province, the Ministry of Energy Resources, the National Energy Investment Corporation, and Guangdong Province, all raised funds to open new avenues for development of Lancang Jiang hydropower; they gained knowledge, and concluded an agreement for a planned large-scale development of the Lancang Jiang hydropower base. The following is a synopsis and prospectus for the Lancang Jiang hydropower base.

### (1) Lancang Jiang Overview and Cascade Development Plan

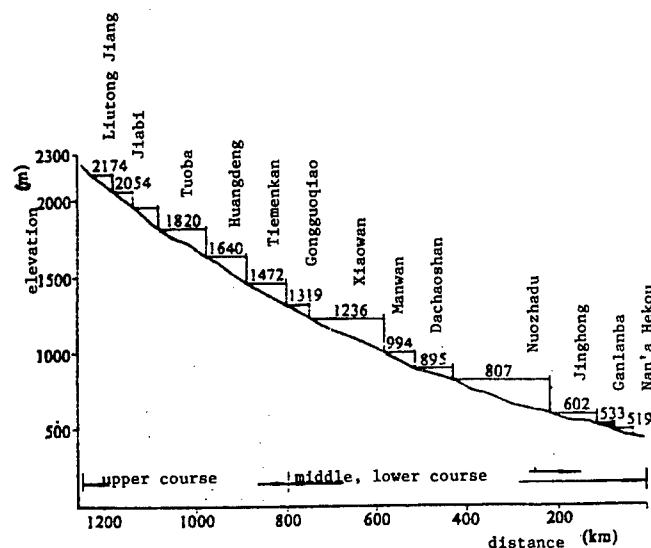
The source of the Lancang Jiang is Tanggulashan in Qinghai, from whence it flows through Xizang and then enters Yunnan, and after exiting the Chinese border, it becomes the Mekong River. One of the well-known international river of Southeast Asia, it is 4,500 kilometers (km) long, has a total fall of 5,500 meters, and its river basin covers 744,000 square kilometers. The segment within China is 2,000 km long, has a fall of 5,000 meters, and its river basin is 174,000 square km. The length of the river within Yunnan Province is 1,240 km; it falls 1,780 meters, and its basin covers 91,000 square km. The multi-year average volume of water flowing out of China is 2,180 cubic meters per second; the annual runoff volume is 68.8 billion cubic meters, and the hydropower potential is about 18 million kW. The river is divided into three segments, the upper reaches extend from Buyi to Tiemenkan, a distance of 437.5 km and falls 938 meters; the middle reaches extend from Tiemenkan to the Lincang Bridge, for a distance of 448.5 km, and falls 584 meters; the lower segment from the Lincang Bridge to the Nan'a River mouth measures 354 km in length and falls 258 meters. The initial plan is to develop the river at 14 levels; the middle and lower reaches, being the most advantageous, are listed as key development segments. In 1986 the Kunming Survey and Design Academy (hereafter referred to as

the Kunming Academy), completed its "Report on the Lancang Jiang Middle and Lower Segment Plan", which passed joint ministerial and provincial approval. The general development policy is mainly to produce electricity, but flood prevention, irrigation, transportation, fishing, tourism, and environmental protection will also be taken into account. The vertical cross-section of the Lancang Jiang mainstream cascades development is shown below:

The Lancang Jiang upper river segment, now only in the initial planning stages, will be developed in six cascades at Liutong Jiang, Jiabi, Wunonglong, Tuoba, Huangdeng, and Tiemenkan, and Tuoba will be the multi-year controlled regulatory reservoir. For the middle and lower river segments, two reservoirs and 8 cascades are recommended at Gongguoqiao, Xiaowan, Manwan, Dachaoshan, Nuozhadu, Jinghong, Ganlanba, and the mouth of the Nan'a, for a total installed capacity of 14.31 million kW, and an annual output of 72.176 billion kWh. Xiaowan, Manwan, Dachaoshan, Nuozhadu, and Jinghong power stations will have a total installed capacity of 12.81 million kW, and their annual output will reach 63.953 billion kWh. There are supplementary advantages to building large regulatory reservoirs at Xiaowan and Nuozhadu. The electric power will be of high quality, and in addition to satisfying Yunnan's load requirements, power will be exported to supply the Guangdong coastal area, a distance of about 1,500 km, using DC 500kV power lines. If the five cascades are completed in 20 or so years, they will have far-reaching effects on Yunnan's economic growth and social development.

### (2) A Brief Sketch of Some Primary Cascade Hydropower Stations

Among the eight cascade hydropower stations of the middle and lower reaches of Lancang Jiang, with the exception of



Manwan which is already under construction, the planning and design units are recommending that the Xiaowan, Dachaoshan, Nuozhadu, and Jinghong projects be started soon. A brief description of these five power stations follows:

#### 1. Xiaowan hydropower station.

Xiaowan hydropower station is located on the border of Fengqing and Nanjian counties. Both banks at the dam site are solid mountain, the topography is symmetrical, and the mountain ridges are 1,000 meters or more above the water level. This hydropower station is the "faucet of the reservoir" in the cascade, and is a key project for the development of the Lancang Jiang. In April 1991, the Water Conservancy and Hydropower Planning and Design Academy's Xiaowan hydropower dam site selection committee agreed on the Xiaowan dam section, preferring a central dam site. The bedrock is solid and the engineering conditions are excellent, suitable for building a 300-meter-high arch dam or a rock-fill dam. According to the dam selection report, the installed capacity of the hydropower station will be 4.2 million kW, the guaranteed output will be 1.7817 million kW, and the annual power output will be [18.951] billion kWh. The normal reservoir elevation will be 1,240 meters, and the reservoir capacity will be 14.557 billion cubic meters, but it will not be a totally long-term regulatory reservoir. Because the Xiaowan reservoir is deep in a mountain ravine, there will be little inundation damage; about 47,800 mu of land will be flooded, and 26,900 people will be relocated. The calculated total investment for the power station is about 8.69 billion yuan. After the power station is built, it should greatly raise the annual power output of Manwan, Dazhaoshan, and other power stations on the lower reaches, with obvious economic advantages.

After assessment and approval by the State Seismological Bureau, the earthquake intensity rating of the dam site was level VIII. In view of the rather complex seismological setting of the area, the basic earthquake intensity rating is quite high, and the engineering scale of the project is huge, so the design must take into consideration the recent  $F_7$  and  $F_{13}$  fault activity, earthquake resistance questions, and main construction materials. Looking at the results so far, although the earthquake question is not limiting construction operations, in the early stages of the work caution is advised, and a worst-case scenario should be considered. Because of the high dam and narrow riverbed at Xiaowan, the flood discharge is large, and therefore one of the key installations that presents a difficult technical problem which must be studied and worked out is the flood discharge energy dissipator. The Kunming Academy will wrap up the feasibility research report by the end of 1991, or shortly thereafter, and it is expected that construction will begin during the Ninth 5-Year Plan.

#### 2. Manwan hydropower station.

Manwan hydropower station, located on the Yun County and Jingdong County border, is well-situated geographically; its energy indicators are excellent, topographic and geological conditions of the dam site are good, reservoir inundation is slight, and it is the first engineering project of

the Lancang Jiang cascade power stations. The bedrock of the dam is mainly rhyolite. The power station has a concrete gravity dam, and behind the dam is a building housing the spillway controls. The dam is 126 meters high, normal reservoir elevation is 994 meters, and capacity of the reservoir is 920 million cubic meters, and it will be a seasonally regulated reservoir. The first-phase independent-operating installed capacity will be 1.25 million kW, with a guaranteed output of 314,000 kW, and an annual output of 6.3 billion kWh. After the Xiaowan reservoir is built, the total installed capacity will go up to 1.5 million kW, guaranteed output will be 796,000 kW, and annual output will be 7.76 billion kWh. The reservoir will displace 3,042 people. The total investment for the station is 1.048 billion yuan. The Kunming Academy designed this project, and the construction is a joint effort by the former Ministry of Water Resources and Electric Power, and Yunnan Province. Preparations began in 1985, work started in 1986, and in 1987 the river was diverted. During construction, bids for contracts were circulated, and it is estimated that the first unit will begin generating power in 1993.

#### 3. Dachaoshan hydropower station.

The Dachaoshan hydropower station is located on the Yun County and Jingdong County border, adjacent to Manwan, upstream. In April 1990, the Water Conservancy and Hydropower Planning and Design Academy, Yunnan Province Planning Committee, and Electric Power Bureau convened the Dachaoshan Hydropower Station Feasibility Study Report Assessment Committee, which agreed to the dam site proposed by the Kunming Academy and Beijing Survey and Design Academy. The bedrock of the dam site is mainly basalt which has great strength and uniformity, and with a little discontinuous intercalated tuff, the rock mass is quite complete. The normal reservoir elevation of this seasonal regulatory reservoir will be 895 meters with a capacity of 884 million cubic meters. Its primary facilities are a riverbed concrete spillway dam, subterranean powerhouse, and a long tailrace tunnel. The maximum elevation of the concrete dam will be 120.5 meters; the installed capacity will be 1.26 million kW; the guaranteed output, 351,300 kW; and annual output, 5.956 billion kWh. The reservoir will flood 11,069 mu of tilled land, and 7,979 mu of forest, displacing 5,774 people. The total static investment is 1.999 billion yuan, and total construction investment is 2.583 billion yuan. The committee believes the Dachaoshan hydropower station is well situated for its scale of engineering. Geological conditions are quite good, inundation loss is slight, engineering requirements are not great, and the electric power economic indicators are optimal for electricity. The Beijing Survey and Design Academy and Kunming Academy will finish the draft design by the end of 1992, and it is expected that construction can begin in the Eighth 5-Year Plan.

#### 4. Nuozhadu hydropower station.

The Nuozhadu hydropower station is located on the border of Simao and Lancang counties with excellent conditions for a reservoir, and it will be one of the regulatory cascade stations on the lower Lancang Jiang. The bedrock of the dam is mainly granite with breccia and arkosite sandstone



in the upper level; it has high strength and the rock mass is complete. The planned normal reservoir elevation of this multi-year regulatory reservoir will be 807 meters, and its capacity will be 22.7 billion cubic meters. The key facilities of the power station will be a dam, an underground powerhouse on the right bank, and a spillway on the left bank; maximum dam height will be 255 meters, its installed capacity will be 4.5 million kW, guaranteed output will be 2.32 million kW, and annual output will be 23.1 billion kWh. The Kunming Academy began the feasibility study in 1991, and it is estimated that construction will be underway in the Tenth 5-Year Plan.

#### 5. Jinghong hydropower station.

The Jinghong hydropower station is located about 5 kilometers up-stream from the capital of Xishuangbanna Zhou. This river segment is accessible by land and water transportation. It will have a multiple utility on the lower segment of Lancang Jiang: electric power, flood control, and shipping. According to the planning report, the dam-site bedrock is amphiplagio-metaconglomerate rock. Its key components are a concrete gravity dam, and a powerhouse located behind the dam; there will be a flood discharge structure and an inclined ship lift. Normal reservoir elevation is to be 602 meters; it will be contiguous with Nuozhadu, upstream; its installed capacity will be 1.35 million kW; guaranteed output, 765,000 kW; and annual output, 7.69 billion kWh.

### (3) Deepened Reforms Drive the Development of Lancang Jiang Hydropower Base

In June 1998, the Ministry of Energy Resources, State Energy Investment Corporation, Guangdong Province, and Yunnan Province, jointly signed the "Agreement on Cooperative Development of Yunnan Energy for Transmission to Guangdong". In April 1991, these parties concluded the Joint-Venture Agreement for Development of the Lancang Jiang Middle and Lower Reaches' Cascade Power Stations, and the Guangdong Seasonal Electric Power Agreement, wherein they agreed to a joint-venture development of the Dazhaoshan, Xiaowan, and Nuozhadu power stations for a total capacity of nearly 10 million kW. These projects are large scale, and will have a far-reaching impact on the economic development of Guangdong and Yunnan, and on energy development in the southwest into the next century. The chief contents of the agreement which was achieved through a full exchange of ideas are:

1. Efforts to get construction of the Xiaowan hydropower station started early in the Ninth 5-Year Plan.

Guangdong Province is willing to join with Yunnan and the State Energy Investment Corporation in the joint-venture project, of which 60 percent will be born by Guangdong, 30 percent by the State Energy Investment Corporation, and 10 percent by Yunnan. All sides will maintain the investment ratio in production rights and electric power shares for the duration, and each will repay their respective loans. After the units become operational, Guangdong will support the power station reservoir and local economic development, and commensurate with annual circumstances, will apportion network power, and will pay Yunnan a specified favorable return per-output cost, and price of electricity for

each kWh supplied: 5 percent within 13 years after the first unit goes operational, and 20 percent after 13 years. Construction of transmission facilities for shipping power from Xiaowan to Guangdong will be built under joint venture between Guangdong Province and the State Energy Investment Corporation. Facilities for transmitting power within Yunnan will be built under joint venture between Yunnan Province and the State Energy Investment Corporation. The parties of the joint ventures agree on the urgency of accelerating the early stages of work on Xiaowan power station, and hope to wrap up the initial design assessment by the end of 1995; 50 percent of the expenditures for the preliminary design will be raised by the Ministry of Energy Resources, 35 percent by Guangdong Province, and 15 percent by Yunnan Province.

2. Efforts to start construction of Dachaoshan hydropower station in 1993.

Because supply of electric power in Yunnan will be tight in the Ninth 5-Year Plan, it is hoped that construction of the Dachaoshan hydropower station will get underway in 1993, and a major portion of it can be operational by 1995. Yunnan Province will provide 40 percent and the State Energy Investment Corporation 60 percent of the investment in this joint venture, and they will enjoy production rights and power benefits in accordance with the investment ratio. One-third of the State Energy Investment Corporation share of the electric power will be exported as arranged by the State.

3. Proceed with the development of Nuozhadu hydropower station under the joint-venture terms used for the Xiaowan hydropower station.

The four parties to the agreement believe conditions for construction of the Nuozhadu hydropower station are very good, and that it will be very profitable. They want to proceed with its construction under the same terms as the Xiaowan station, expect to begin construction when Xiaowan is finished, and hope that both projects will be completed within 15 to 20 years. They hope to submit the feasibility study in 1995, and finish the preliminary plan before the year 2000. The early stages will be financed with accumulated funds, 50 percent provided by the Ministry of Energy Resources, 35 percent by Guangdong Province, and 15 percent by Yunnan Province.

In addition, after the four parties negotiated the construction of the Lubuge hydropower station, they reached unanimous agreement in principle on all questions pertaining to sending power seasonally to Guangdong, on how much and when, and the particulars of calculating and accounting the price of electricity and power construction funds.

4. Several points of interest.

The joint investment agreement of the Ministry of Energy Resources, State Energy Investment Corporation, Guangdong and Yunnan provinces for development of the Lancang Jiang mainstream hydropower base opened the way for hydropower construction, and is the culmination of deepened reforms.



1. The quadripartite agreement is in keeping with the national energy policy of promoting hydropower as one of the strategies for developing China's energy industry in the face of daily worsening shortages of electric power in China, the restrictive coal transportation situation, and environmental protection, which has steadily been forced upon the public consciousness, and therefore, joint venture development of Lancang Jiang middle and lower reaches' cascade hydropower stations is not only a benefit to furthering the development of the hydropower industry, but also a benefit to improvement of the energy structure.

2. Sharing advantages, developing together.

Under the impetus of economic system reform, with national support to make full use of Yunnan's hydropower advantages and Guangdong's electric power market advantages, an arrangement was worked out to share complementary advantages and develop together. Both provinces have long-range strategic targets in mind; Yunnan's position is to basically resolve the problem of serious shortage of funds to develop its hydropower resources on its own. The arrangement is an important guarantee of electric power needed to develop the economy of the whole province; which is not only developing a river, but more importantly, will be the stimulus for development and vitalization of Yunnan. From Guangdong's position, as it provides stable and long-range electric power, and strengthens logistics, it will be an energizer of further development. In the national view, it is making full use of the national investment conduit to meet the inevitable challenge of the hydropower industry.

3. For the solidification and development of socialization of the means of production.

Cooperative multilateral use of the joint-stock method of raising funds for construction under the aegis of public ownership of the means of production, is in keeping with the laws of socialism, and embodies the assistance and support of economic development of minority people's areas, and yet underdeveloped poor areas within the region, to lead the economic development of the region and frontier minority people's areas on the road to prosperity.

4. Many channels for raising funds for hydropower construction.

To accelerate the development of hydropower, many channels for raising funds must be used in order to develop a

group of large-sized hydropower stations. Hydropower construction funds can be raised within the province, or funds can be gotten from outside sources, even foreign funds; and under certain conditions, the approach may be used of taking funds from outside the province and sending electric power out of the province. Only by using national investment channels over and above the provincial and regional channels, can hydropower construction be accelerated. That is the road to success for electric power development and reform.

5. Raising funds for early stage efforts.

At present, the early-stage work for hydropower construction cannot keep up, and such design preparations as there are far short of fulfilling hydropower development needs. One important reason for this situation is that outlays for early-stage work are insufficient. Given the realities of the hydropower development situation, in order to build and stabilize funding sources for early-stage work, it is necessary that state funds for prospecting for hydropower resources be properly increased, and part of the new tax of 2 fen per kilowatt-hour of electricity be used for hydropower early-stage work; that a fund be set up to increase investment, and outlays be made for hydropower early-stage work; and at the same time, following the Xiaowan and Nuozhadu approach, the national, provincial, and regional funds should be raised according to fixed ratios; for it is summarily evident that only with high quality completion of early-stage work can national policy decisions be complied with and hydropower construction be accelerated.

Cooperative development of Lancang Jiang middle and lower reaches hydropower engineering is a forward-looking strategy resounding with the distant vision and sagacity of Guangdong, Yunnan, and the central departments. This interchanging of economic and energy advantages, rejoining of the energy-rich with the energy-poor, the major power resources with the major consumers, is a new model for economic development. It is in keeping with the policy of national economic reform, and with the objective laws of power-network development, and must fulminate its life-force. It not only will have long range impact on Lancang Jiang development, but will invigorate the administrative reform of the entire national electric power construction industry.

### Eastern Sichuan Gas Fields Lead the Nation in Output, Economic Benefit

926B0053A Shanghai WEN HUI BAO in Chinese  
18 Jan 92 p 1

[Article by Chen Qibing [7115 0796 0365]]

[Excerpt] Several hundred large- and middle-sized military, chemical, metallurgical, etc. industries, and an estimated several hundred thousand people in the provinces of Sichuan, Yunnan, and Guizhou are using natural gas transmitted from eastern Sichuan gas fields. These gas fields are the largest in the country, and lead the nation in production and profits.

The eastern Sichuan gas fields connect with Hunan and Hubei in the east, stretch westward to the Huayingshan range, and from Shaanxi in the north to Guizhou in the south. Within the area are high mountains and deep valleys, which present difficult conditions for gas extraction. Beginning in the 50s, the national petroleum and natural gas industrial sectors pooled their forces, made investments, and began drilling, extraction, transportation, and refining operations on the 55,000 square kilometers of gas fields. Over 5,000 employees of the Eastern Sichuan Development Corporation in charge of the eastern Sichuan gas fields, overcame the difficulties of complex geographic and geological conditions, widely dispersed gas fields, earthquakes, drought, winds and storms, and gave equal treatment to scientific research as well as production, relentlessly intensified enterprise reforms, and accelerated the pace of construction. By 1990, they had drilled 567 wells in 80 different structures for a total drilling depth of 1.87 million meters, brought in 336 gas wells, and found reserves of 117.126 billion cubic meters of gas. By June 1991, 17 gas fields had gone into production on 7 oil-bearing structures. Over the years 221 gas wells have gone into full-scale production, and the accumulated volume of gas extracted was up to 37.714 billion cubic meters. The annual production is one-fourth of the total annual output for the whole country. [passage omitted]

### Major Fields Found in Tarim, East China Sea, Ordos

926B0065C Beijing RENMIN RIBAO in Chinese  
8 Feb 92 p 1

[Article by reporter Zhu Youdi [2612 1635 2769]: "Successive Major Breakthroughs in Oil and Gas Surveys, Several Important Oil and Gas Fields Discovered at Tarim, East China Sea, Ordos, Etc."]

[Text] Successive important breakthroughs have been made in China's oil and gas surveys. Several important oil and gas fields have been discovered in the Tarim, East China Sea, Ordos, and Songliao Basins.

According to the Ministry of Geology and Mineral Resources, industrial oil and gas flows were obtained from the Sha-31 well, Sha-29 well, and Sha-17 well on the Aqkkol uplift in Tarim Basin, confirming that the large Aqkkol uplift is an important zone of rich oil and gas accumulation. Excellent oil and gas indications were also seen in the Shaxi

structure and Daliya structure and they may provide industrial oil and gas flows. Major advances have also been made in new areas in natural gas exploration in Ordos Basin. Logging has been completed for the E-5 well built on the Tabamiao structure and it has stable daily output of more than 10,000 cubic meters of natural gas. In natural gas exploration in the southern part of Songliao Basin, daily natural gas output from the Long-1 well built in 1991 has been 100,000 cubic meters and daily natural gas output from the Songnan 30-1 well built in the Lishu depression has been 27,000 to 31,000 cubic meters, revealing substantial prospects for gas exploration.

In geological surveys of East China Sea oilfields, daily outputs of 64.6 cubic meters of crude oil and 39,000 cubic meters of natural gas have been obtained from the Baoyunting-2 well in the Xihu depression, which has expanded the oil and gas-bearing area of the Baoyunting structure. After 1 year of work, five oil and gas wells have been drilled in new areas and new structures and they have added several crude oil and natural gas control reserves and expanded the oil and gas-bearing area by 21.6 square kilometers, providing a reserve base area for oil and gas reserves for China.

### Breakthrough Reported in Turpan-Hami Exploration

926B0052A Lanzhou GANSU RIBAO in Chinese  
2 Jan 92 p 1

[Article by correspondent Ma Huibang [7456 2585 6724] and reporter Wang Zhenshan [3769 2182 1472]]

[Text] Yet another breakthrough has been made in prospecting for petroleum in the Turpan-Hami Basin in Xinjiang. In 1991, three oil fields were found and confirmed at Wenjisang, Qiudong, and Kekeya. Along with the Shanshan, Yilahu, and Qiuling oil fields found earlier, six oil fields with impressive proven reserves have been discovered and confirmed in the Turpan-Hami Basin. The China Petroleum and Natural Gas Corporation lists Qiudong and Kekeya oil fields among the important finds of 1991.

Activity began in the Turpan-Hami Basin in September 1987; the Shanshan and Yilahu oil fields were found in 1989, and Qiuling in 1990. On 12 April 1991, the Wen-1 oil well produced a good flow of oil and gas condensate, demonstrating the high potential of Wenjisang oil field. After that, the Qiudong-3 oil well on the Qiudong structural zone in the basin, and the Ke-7 well at the western end of the Shanshan structural zone, also brought up high volumes of oil and gas.

### Qinghai's 1991 Crude Output Breaks 1-Million Ton Mark

926B0057B Xining QINGHAI RIBAO in Chinese  
27 Dec 91 p 1

[Article by reporter Chen Zhi [7115 1807]]

[Excerpt] News has been received from western Qaidam Basin that Qinghai oil field broke the 1-million-ton mark for the first time at 8 o'clock on 23 December.

In recent years, the Qinghai Petroleum Administrative Bureau has concentrated its efforts on reaching an output of 1 million tons per year. The Bureau set up a rigorous responsibility system at all positions, and achieved balanced performance from top to bottom throughout the organization. The Bureau actively applied new technology, and implemented measures to increase production, and in the end, fulfilled the annual plan ahead of schedule and over quota, bringing a satisfying conclusion to the 37-year-struggle of two generations of Qaidam oil field workers. [passages omitted]

### **Xinjiang's Crude Oil Output Breaks 7-Million-Ton Mark**

926B0057A Urumqi XINJIANG RIBAO in Chinese  
5 Jan 92 p 1

[Article by correspondent Yi Peixian [5902 1014 7359]]

[Text] The Xinjiang Petroleum Administrative Bureau's crude oil output, which has been growing for 10 successive years, broke the 7-million-ton mark in 1991, moving the bureau into fourth place in the nation-wide petroleum system.

During the Sixth 5-Year Plan, the Xinjiang Petroleum Administrative Bureau's crude oil output, which was 3.8 million tons in 1981, increased to 5 million by 1985; and during the Seventh 5-Year Plan, the average annual increase was 360,000 tons, building to a production volume in 1990 of 6.8 million tons. In the first year of the Eighth 5-Year Plan crude oil output reached 7.02 million tons.

The Xinjiang Petroleum Bureau was able to sustain the growth of its output mainly through strengthening enterprise administration, actively promoting and relentlessly perfecting flexible contract management responsibility system and highly effective project administration. In 1988, 92.9 percent of the units under contract with the Bureau came under the contract management responsibility system, and the investment figure for project management for 1989 was over 88 percent of the Bureau's total investments. Priority was then placed on petroleum prospecting in an effort to open up new oil bearing territories. In plans, deployment, and investments, this Bureau gave priority to supporting petroleum prospecting. The Fengcheng, Xiaxijie, and Hongshanzi oil fields were discovered in recent years, one after the other, on the northwest rim of the Junggar Basin; and in eastern Junggar Basin the Huoshaoshan and Beisantai oil fields were discovered; and again, in 1991, in the heart of the Gurbantuguit Desert, high flows of commercial grade oil and gas were discovered. Prospecting in the deep carboniferous and Permian systems in the interior of Karamai oil field has identified new oil bearing areas and geological reserves. All the while, they continued to readjust the potential of the old oil fields, and took strong measures to maintain steady output in the older areas. From 1988 to 1991, measures were passed which, altogether, increased output by over 2.3 million tons, and average annual increase in production was 560,000 tons. To offset the diminishing annual output from old oil fields, construction for production capacity has been unrelenting in recent

years. Construction for 1 million tons of capacity and up has been completed every year from 1988 to 1991, and that has guaranteed steady and increased outputs from the oil fields.

### **Forecasting Prospects for Natural Gas Industry From Results of Exploration in the Seventh 5-Year Plan**

926B0064 Chengdu TIANRANQI GONGYE  
[NATURAL GAS INDUSTRY] in Chinese  
Vol 12, No 1, 25 Jan 92 pp 10-15

[Article by Yao Chao [1202 6389] and Ai Guimei [5337 2710 2734] of the China Petroleum and Natural Gas Corporation Exploration Bureau: "China's Natural Gas Industry Development Prospects in View of Natural Gas Exploration During the Seventh 5-Year Plan"]

[Text] Abstract

This article summarizes China's primary achievements in natural gas exploration during the Seventh 5-Year Plan, analyzes the factors behind improvement of exploration results, and proposes near-term gas exploration directions and the factors restricting development of China's natural gas industry. The article states that establishing special natural gas exploration projects is an effective way to improve exploration results and overcome certain restrictive factors, and will inevitably spur rapid development of our natural gas industry.

Key terms: China, natural gas exploration, achievements, results, restricting factors, exploration prospects

### **I. Current Development Situation in the Natural Gas Industry**

China's natural gas industry has developed very quickly since Liberation. Excluding Taiwan Province, 106 gas fields had been discovered up to the end of 1990. We have built a natural gas exploration staff from nothing and now have a fully integrated one ranging all the way from geology, geophysics, exploratory drilling, and testing to comprehensive research. There have been continual expansions in the scope of natural gas exploration and we have moved from Sichuan Basin to open up over 10 basins and regions including Songliao, Ordos, Bohai Bay, Qaidam, Junggar, Tarim, and others. Still, the development of our natural gas industry is far from able to satisfy China's industrial and agricultural development needs and there are prominent contradictions in these areas:

1. We have abundant natural gas resources, about 12.4 percent of the world's total natural gas resources, but the degree of proven reserves is very low, just 3.6 percent of our resources, whereas the degree of proven reserves for petroleum has now reached 16 percent, so there is a significant loss of coordination in the proportional development of oil and gas.

2. Oil and gas output proportions are uncoordinated. In 1989, for example, the oil-gas output ratio was 1:1.02 in the United States and 1:1 in the Soviet Union, with the world average being 1:0.62, but China's ratio was just 1:0.1.

3. Of the gas fields already discovered at present, there are few large and medium-sized gas fields and many small gas fields, so the results of natural gas exploration are poor.

4. In the gas reserves newly proven over the past several years, the proportion accounted for by combined oil and gas exploration regions is low, especially in the industrially developed region of Bohai Bay which has large demand for natural gas. The limited increase in reserves has resulted in a prominent contradiction between supply and demand.

5. Natural gas accounts for a too-small proportion of the structure of primary energy resource consumption in China, just 2.1 percent in 1989, which is a great disparity compared to the world average level of 19.9 percent. This is extremely ill-matched to China's enormous natural gas resources.

Since the 1980's, China has been giving increasing attention to the role of natural gas in the development of industry and agriculture, urban construction, and the prevention of environmental pollution, and has proposed the principle of "combined development of oil and gas". Since the Seventh 5-Year Plan, we have opened up special natural gas exploration regions and discovered over 10 gas fields in several large basins in China which have substantially increased our proven natural gas reserves. During this period, the newly-proven gas reserves in China account for 42.33 percent of the total gas reserves proven in China in history. Newly-proven gas reserves on the mainland account for 30 percent of total proven gas reserves on the mainland in the past, including newly-proven reserves in special natural gas exploration regions which account for 80 percent of the proven reserves on the Chinese mainland.

## II. Major Achievements in Natural Gas Exploration During the Seventh 5-Year Plan

There were 10 major achievements on a national scale during the Seventh 5-Year Plan.

### A. Discovery of the readily available porous Moxi gas field in Sichuan Basin

Moxi gas field is located in the southern part of the gently-sloping structural zone on the central uplift in Sichuan Basin. It is a gently-sloping short-axis anticline with a NE strike. The middle Triassic system Leikoupo group Lei-1<sup>1</sup> strata top closed area covers 205.5 km<sup>2</sup> with a closure of 87 m. Exploratory drilling of a total of 21 wells has been completed in this gas field. Five sets of industrial gas strata were discovered, the Jia-2 (T<sub>1</sub>c<sup>2</sup>), Lei-1<sup>1</sup> (T<sub>2</sub>r<sup>1</sup><sub>1</sub>), Xiang-2 (T<sub>3</sub>h<sup>2</sup>), Xiang-4 (T<sub>3</sub>h<sup>4</sup>), and Xiang-6 (T<sub>3</sub>h<sup>6</sup>). Among them, the Lei-1<sup>1</sup> is the primary gas strata. The lithology of the reservoir strata is porous dolomite, and 10 of the exploratory wells produced industrial gas flows with outputs generally in the range of 15,000 to 30,000 m<sup>3</sup>/d. The proven gas-bearing area covers 120 km<sup>2</sup>, so it is a medium-sized gas field.

The discovery of the Moxi Lei-1<sup>1</sup> porous reservoir strata resulted in an historical transformation of natural gas exploration in Sichuan. In the past, the focus was on searching for fissure-type gas pools. The success rate in exploratory wells was low and the results of exploration were poor. Very few large and medium-sized gas fields

were discovered. Now, not only has the realm of searching for readily available porous gas accumulations in Sichuan Basin been opened up, but new understandings have also occurred in the guiding ideology in exploration.

### B. Major breakthroughs in high-slope structure Carboniferous system gas pool exploration in eastern Sichuan

Since the discovery of a Carboniferous system gas pool in the Xiangguosi structure in eastern Sichuan in 1977, a total of more than 20 gas fields and gas-bearing structures have been discovered and they have become the primary target strata for exploration in this region. For a period in the past, however, given restrictions by technical and knowledge conditions at the time and the substantial discrepancy between the shape of ventral structures from seismic interpretation and the actual shape, nearly all of the first group of preliminary exploratory wells in 10 high-slope structures suffered setbacks. Through comprehensive analysis of geological, seismic, logging, and other data of the failed wells during the early part of the Seventh 5-Year Plan, we began with clarification of the shape of underground structures and through gradual exploration and repeated practice and understanding, we established a set of work procedures for processing and interpreting seismic data centered on geological and physical models. The seismic interpretation achievements submitted on the basis of these procedures have now gradually approximated the actual situation of underground structures. This produced major breakthroughs in exploratory drilling over the past several years in the Dachi Ganjing, Tieshan, Qilixia, Datianchi, Yun'an-chang, and other high-slope structural zones. Exploratory drilling was carried out on more than 20 local structures and the exploration success rate surpassed 66 percent. In addition, over 10 high-output gas wells greater than 1 million m<sup>3</sup>/d were obtained from the Gaofengchang, Diaozhongba, Mopanchang, Wubaiti, Yunhezhai, Tieshannan, and other structures. In several high-slope structures, industrial gas flows were obtained from the footwall of primary faults as well as structural traps on the hanging wall of primary faults, which has opened up new realms in exploration for gas in steep-slope anticlines.

The Carboniferous system is distributed over a wide area in eastern Sichuan. It is in the fissure-porous reservoiring category, the material properties of the reservoir strata are good and the logging output is high. The reserves are rich (generally 200 to 400 million m<sup>3</sup>/km<sup>2</sup> with a maximum of 570 million m<sup>3</sup>/km<sup>2</sup>). The gas pools are mainly controlled by structural traps and structural-stratigraphic traps. Industrial gas flows usually can be obtained by drilling in different categories of structural traps and in different locations in the traps.

There are still great potential resources to be proven in the Carboniferous system in eastern Sichuan. We have already discovered 123 structural traps and the resources in the traps account for 11.7 percent of the resources in the Sichuan Basin. Moreover, there are several structural traps where exploratory drilling has not been done and they are ideal regions to search for "double high" large and medium-sized gas fields in the near term.

### **C. Pingluoba gas field discovered at the southern end of the premontane zone of Longmen Shan**

The Pingluoba structure is a concealed structure with good preservation conditions, integral shape, and rather high amplitude. The region is located at the southern margin of the upper Triassic system Xiangxi group coal series gas generating depression in western Sichuan. Moving in a vertical direction, because of the development of ancient fractures during the Indo-Sinian period on the eastern flank of the structure, the Xiang-2 and Xiang-4 segment gas reservoir strata on the fault's hanging wall and the upper part of the Xiangxi group on its footwall are very close to the coal series, which is extremely favorable for the rich accumulation of natural gas. The Pingluo-1, -2, and -5 exploratory wells have already been drilled into this structure and they obtained industrial gas flows from, respectively, the Xiang-2 and Xiang-4 segments. The discovery of this gas field reveals the excellent gas exploration prospects of the Xiangxi group in the southern part of the western Sichuan depression.

### **D. Major breakthroughs in natural gas exploration in the central part of Ordos Basin**

Since the establishment of a special natural gas exploration project in Ordos Basin in 1986, there have been major advances in exploration work and five rather good gas-bearing areas and blocks (Zhenchuanbao, Zizhou, Yukou-Jiaxian, Tianchi, and Jingbian-Hengshan) and five sets of gas-bearing strata systems (upper Paleozoic Shihezi group and Shanxi group, Carboniferous system Taiyuan group and Benxi group, and lower Paleozoic Ordovician system weathered crust) have been discovered. There are 28 gas wells that have produced more than 10,000 m<sup>3</sup>/d. This is particularly true for the last 2 years of the Seventh 5-Year Plan within the Jingbian-Hengshan region covering about 16,000 km<sup>2</sup> on the sloping zone on the east side of the northern end of the central paleouplift where eight gas wells in the Ordovician system weathered crust have produced more than 100,000 m<sup>3</sup>/d, including the resistance-free gas flow of as much as 1 million m<sup>3</sup>/d from the Shan-5 and -6 wells. This weathered crust is widely distributed over this area and is relatively stable in thickness and buried at suitable depths (2,500 to 3,400 m), so large gas-bearing areas and blocks may have formed. The reservoir strata in this region are rather thin, however, and their material properties are poor and the abundance is rather low. Still, analysis of the geological conditions indicates that there is still a possibility that moderate and high abundance gas-bearing areas and blocks may be found. The key now is to reinforce exploration work and conduct intensive research on the scope of the distribution, variational regularities, formation and accumulation conditions, and sealing conditions of reservoir strata.

### **E. Tainan gas field discovered in the Quaternary system in eastern Qaidam Basin**

Tainan gas field is a Quaternary series biogenetic gas pool buried at relatively shallow depths and controlled by an anticline. The gas reservoiring strata are Quaternary system non-lithified loose powdery sandstone. A total of six exploratory wells have been drilled in this gas field and four of the

wells produced industrial gas flows. A total of four gas-bearing strata groups were discovered. There is a rather high possibility of generation in single gas strata series and the gas output of most was greater than 200,000 m<sup>3</sup>/d.

Since the start of exploration in the eastern part of Qaidam Basin in the 1950's, four small gas fields have been located. Since the Seventh 5-Year Plan, by applying special advanced seismic processing technology and deploying exploratory wells according to the appearance of "velocity pull-down" effects of gas pools in the seismic profile and various types of response characteristics, only six wells had to be drilled to locate the medium-sized Tainan gas field. The discovery of this gas field had major significance for re-evaluation of the previously discovered Sebei No 1 and No 2 gas fields. These two gas fields have similar geological conditions to those of Tainan gas field and are located in the same Quaternary series gas generating depression. The gas-bearing areas and structural amplitudes are both greater than Tainan gas field but their reserves are poorer than Tainan gas field. This obviously is unusual. After analysis, the feeling was that these two old gas fields still had great potential and that with improvements in drilling, logging, and testing technologies, new vigor could certainly be restored to these gas fields.

### **F. Rather good achievements in shallow strata natural gas exploration in Songliao Basin**

Shallow strata in Songliao Basin refers to the Fuyu, Yangda Chengzi, and other petroliferous strata in the upper part of Segments 3 and 4 of the lower Cretaceous Quantou group. During the Seventh 5-Year Plan, substantial achievements were made in moderate and shallow strata natural gas exploration, especially with the discovery of Wangjiatun and Shengping gas fields from 1987 to 1988 where the practical natural gas reserves accounted for 64.3 percent of the total gas reserves in the entire basin. The abundance was 224 million m<sup>3</sup>/km<sup>2</sup> and they are medium-sized to small gas fields. The gas generating strata are the Fuyu and Yangda Chengzi oil strata and the gas pools are lithologic-structural compound traps. These achievements revealed that the Fuyu and Yangda Chengzi oil and gas strata are important target strata in the search for gas in the basin.

### **G. Significant progress in deep strata natural gas exploration in Songliao Basin**

Deep strata in Songliao Basin refers to Segments 1 and 2 in the lower Cretaceous Quantou group and strata beneath them, including the Dengloulou group, Jurassic system, and bedrock weathered crust. Industrial gas flows were obtained from all of these strata. The Zhaoshen-1 well produced 13,600 m<sup>3</sup>/d from the weathered crust while the Fangshen-1, -2, and -4 wells each produced gas flows of 28,000 to 48,100 m<sup>3</sup>/d from the Dengloulou group, including the Fangshen-4 well which without upgrading erupted with 25,000 m<sup>3</sup>/d of gas. Industrial gas flows were also obtained in the Lican-1 well and Si-2 well from the Quantou group and Jurassic system, respectively. These achievements fully revealed the substantial potential for deep strata natural gas in Songliao Basin. Research indicates that the primary gas source rock

for deep strata natural gas is coal series and dark argillaceous rock in deep Jurassic system depressions. The Xingshan-Yingshan, Wuyu'er, Suihua, and other Jurassic grabens have enormously thick Jurassic system sediments and are favorable regions to search for gas in the future.

#### **H. Discovery of Mazhuang gas field in Junggar Basin**

Mazhuang gas field is located in the Tai-3 fault-block region at the conjunction of the Tianshan premontane fault-folded zone and Zhangbei uplift in the southern part of Junggar Basin, where six wells produced industrial gas flows. Several sets of reservoir strata were discovered during exploratory drilling. The primary reservoir strata are the Jurassic system Qigu group, followed by the Toutunhe group and Badaowan group. The lithology of the reservoir strata in the Qigu group is fine sandstone, medium-grained sandstone, and conglomeratic sandstone with rather good material properties.

The natural gas in this gas field has two different properties. Based on analysis of gas components and carbon isotope data, the feeling is that the natural gas from the area of the Tai-10 and -17 wells at the northwestern end is compound gas composed of coal-formed gas and oily gas and that the main gas source comes from the Jurassic and Triassic systems in Fukang depression at the northwestern margin. The natural gas from the main positions in the structure to the southeast of the Tai-17 and -10 wells is mainly oily gas and the primary gas source comes from Permian system gas source rock in the premontane depression.

#### **I. High-output gas flows from the Paleozoic in the Lunnan region of Tarim Basin**

The Lunnan region is located in the Tabei [northern Tarim] uplift zone in Tarim Basin. Gratifying achievements have been made in oil and gas exploration during the past 2 years, with the drilling of several high-output oil wells in the Mesozoic and Paleozoic and high-output gas flows from drilling in the Paleozoic Ordovician and Carboniferous systems. At the Lunnan-9 well, the Carboniferous system produced 123,000 m<sup>3</sup>/d of gas. At the Lunnan-10 well, the Ordovician system produced 334,000 m<sup>3</sup>/d of gas. At the Lunnan-4 well, testing in the Ordovician system also produced industrial gas flows. Exploratory drilling by the Ministry of Geology and Mineral Resources in this region also discovered high-output gas flows from the Paleozoic. Analysis of the data indicates that this region has substantial natural gas resources. Exploratory drilling has confirmed that the Tazhong [central Tarim] uplift also has abundant natural gas resources. Thus, the prospects for natural gas exploration in Tarim Basin are optimistic.

#### **J. Discovery of Ya 13-1 gas field in the South China Sea's Qiongdongnan Basin**

Ya 13-1 gas field is the first large marine gas field discovered in the South China Sea as well as a rather large gas field with one of the higher reserve abundances discovered in China so

far. Its reserves account for 31.2 percent of the proven gas reserves during the Seventh 5-Year Plan. The discovery of this gas field has opened up a new situation in China's maritime gas exploration.

Ya 13-1 gas field is in the ARCO cooperative block and was discovered using high and new seismic technology involving precision processing and interpretation of seismic data as well as some unique processing which used seismic information to assess sedimentation environments and distributional laws of gas-bearing sand strata, which reduced the amount of work involved in exploratory drilling. A large gas field was found after drilling just five exploratory wells.

The generation strata in this gas field are lower Tertiary Lingshui group sandstone. The reservoir strata are of great thickness and have good material properties. The components of the natural gas are primarily methane, with a content of as much as 85 percent, and it is coal-formed gas.

#### **III. Significant Improvements in the Results of Natural Gas Exploration on the Chinese Mainland During the Seventh 5-Year Plan**

China's natural gas industry got off to a rather late start. With the exception of Sichuan, exploration was done in conjunction with petroleum exploration in most regions and the newly-opened special natural gas exploration regions were still in the early exploration and evaluation phase. The amount of work invested was small and it took about 5 years before results were seen. Thus, the results of natural gas exploration were consistently rather poor. In 1984, for example, gas accounted for just 6.6 percent of the new increases in recoverable oil and gas reserves in China (calculated at 1,000 m<sup>3</sup> = 1 t of oil and recoverable reserves calculated at 70 percent for gas and 30 percent for oil, the same holding true below).

After the substantial breakthrough in natural gas output in 1985, the Petroleum and Natural Gas Corporation formulated the principle of "combined exploration for oil and gas" during the Seventh 5-Year Plan and established special natural gas exploration projects in several of China's large basins. This gradually moved natural gas exploration onto the right track and the results of exploration have improved each year.

1. There has been an increase each year of natural gas as a proportion of newly-added oil and gas reserves on the Chinese continent. Natural gas accounted for 10.9 percent of the new increases in recoverable reserves of oil and gas in 1986. This proportion had risen to 21.88 percent by 1990, an increase of 10.98 percent over 5 years.

2. Since 1986, following the establishment of special natural gas exploration projects in Sichuan, Ordos, northern Songliao Basin, eastern Qaidam Basin, and other basins and regions, there have been continual improvements in the results of natural gas exploration in special natural gas exploration regions. By the end of 1990, recoverable reserves had approximated and caught up with the results of oil exploration (Figure 1 and Table 1).

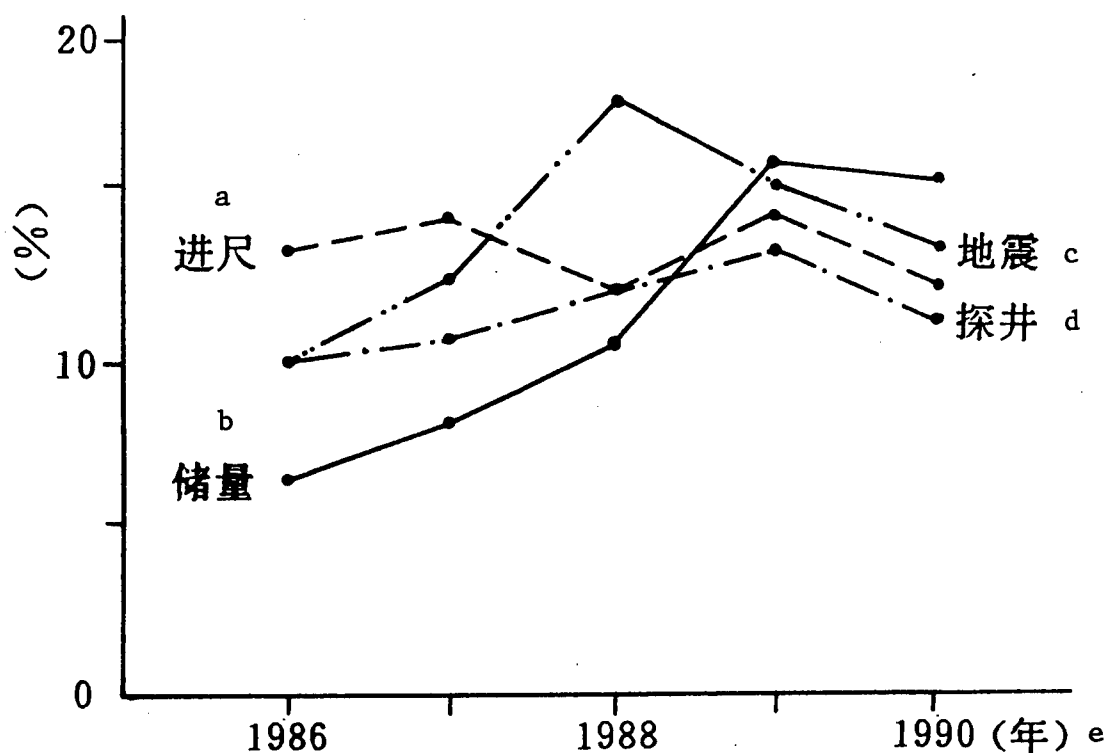


Figure 1. Reserves and Amount of Work in Special Natural Gas Exploration Regions as a Percentage of Total Oil and Gas Reserves and the Amount of Work in China During the Seventh 5-Year Plan

Key: a. Driving footage; b. Reserves; c. Seismic; d. Exploratory wells; e. Year

Table 1. Comparison of Oil and Gas Exploration Results in China During the Seventh 5-Year Plan

Year	Oil/Gas	Recoverable proven reserves		
		Per well (million m <sup>3</sup> )	Per meter of driving footage (1,000 m <sup>3</sup> )	Per kilometer of seismic profile (1,000 m <sup>3</sup> )
1986	Oil	169	70.4	1,534
	Gas	102	30.4	926.7
1987	Oil	146	58.2	1,219
	Gas	104	31.3	756
1988	Oil	163	63.6	1,723
	Gas	136	53.0	929
1989	Oil	168	70.2	1,059
	Gas	263	116.4	1,170.7
1990	Oil	164	59.2	987.3
	Gas	223	79.6	1,095

Note: Natural gas results refer to special natural gas exploration regions

Figure 1 shows that recoverable reserves from special natural gas exploration regions as a percentage China's recoverable oil and gas reserves increased each year during the Seventh 5-Year Plan, rising from 6.7 percent in 1986 to 15.65 percent in 1990, an increase of 8.95 percent. During the same period, however, the amount of exploration work only increased by less than 1 percent. The average amount

of seismic work accounted for 14.15 percent of the total for China, exploratory wells accounted for 11.24 percent of the total number of exploratory wells in China, and the driving footage in exploratory wells accounted for 12.62 percent of the total exploratory well driving footage in China.

Looking at the converted proven recoverable natural gas reserves per exploratory well, per meter of driving footage,

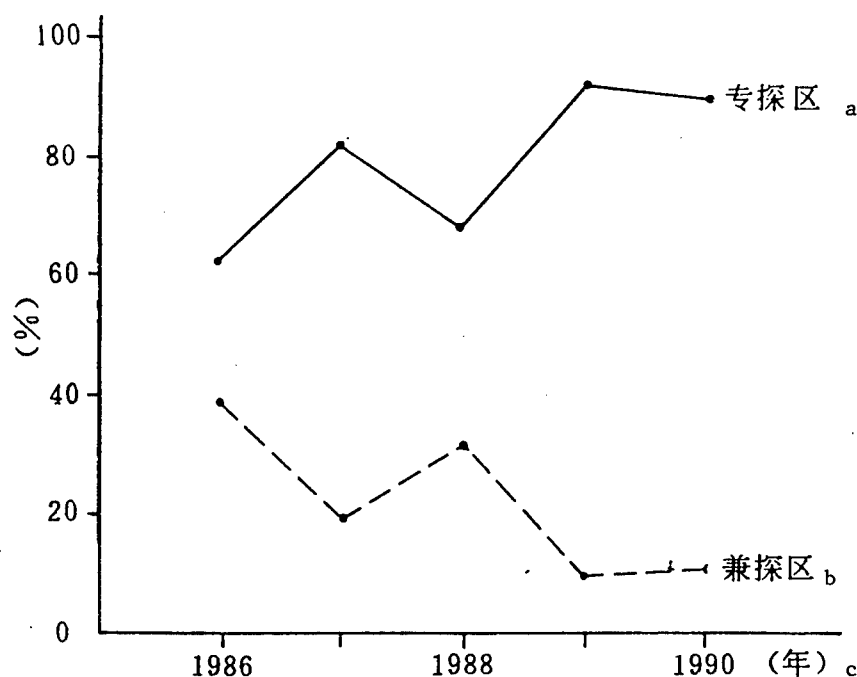


Figure 2. Proven Recoverable Gas Reserves in Special Natural Gas Exploration Regions and Combined Exploration Regions as a Percentage of Total Proven Recoverable Reserves in China During the Seventh 5-Year Plan

Key: a. Special exploration regions; b. Combined exploration regions; c. Year

and per kilometer of seismic profile (Table 1), one can see a significant increase every year in special natural gas regions from 1986 to 1990 and the average results nearly doubled. Over the same period, however, the results of oil exploration basically held steady.

Looking at China's proven recoverable natural gas reserves, there was also a significant increase in proven reserves in special natural gas exploration regions, rising from 62.1 percent of China's total proven reserves in 1986 to 86.50 percent in 1990 (Figure 2).

In summary, the establishment of special natural gas exploration projects was a primary factor behind the improvement of exploration results during the Seventh 5-Year Plan as well as an effective route for rapid development of natural gas exploration throughout China in the future.

#### IV. Broad Prospects for Natural Gas Exploration on the Chinese Mainland

China's natural gas resources account for 12.4 percent of the world's natural gas resources and we have become a major natural gas resource country, ranking only behind the Soviet Union (about 13.38 billion m<sup>3</sup>) and the United States (about 4.39 billion m<sup>3</sup>). However, China's proven gas reserves at present amount to less than 3.6 percent of our resources. Thus, we have a powerful resource foundation for development of our natural gas industry.

Looking at geological conditions, the area and volume of sedimentary rock in China is only less than the Soviet

Union, United States, and Canada, whereas the rate of proven gas reserves relative to China's area and volume of sedimentary rock is far less than in these countries. There are four characteristics in the geological conditions in the formation of the world's large gas fields: large basins and abundant resources, thick and stable capping strata, the presence of large-scale anticlines or lithologic traps, and rather good reservoiring strata. These conditions exist in many of the basins on the Chinese mainland and we have 10 basins covering areas greater than 100,000 km<sup>2</sup>. Moreover, China is the world's leader in coal reserves and we have three huge coal-bearing basins with resources in excess of 500 billion t, so we have favorable conditions for exploration for coal-formed gas resources.

According to existing exploration and research achievements, these are the primary favorable regions for natural gas exploration in the near term:

1. Sichuan Basin is already known to be a large petroliferous basin where gas predominates. The degree of exploration is relatively high, but it is still rather low compared to several basins in the United States, with an average of just one exploratory well for every 69 km<sup>2</sup>. Moreover, over an area of about 50,000 km<sup>2</sup> from central Sichuan to northwest Sichuan, the degree of exploration is also relatively low. Thus, there are broad prospects for exploration in this basin.

2. In the Ordos Basin, exploration for natural gas was carried out over an area of about 100,000 km<sup>2</sup> during the Seventh 5-Year Plan and several industrial gas wells were obtained. This is particularly true for the eight gas wells with outputs in excess of 100,000 m<sup>3</sup>/d drilled in the weathered



crust at the top of the Ordovician system in the central part of the basin during the past 2 years, which illustrate the situation of a large gas-bearing area in this basin, making it a key region for gas exploration in the near term.

3. As mentioned previously, industrial gas flows were drilled from the deep strata Denglouku group, Jurassic system, and weathered crust in Songliao Basin. In particular, the outputs were rather high from the Fangshen-1, -2, and -4 wells in the Songfangtun region, and the presence of gas strata was also interpreted from logging in the Denglouku group at the Fangshen-5 well, revealing the excellent gas exploration prospects of deep strata, so exploration should be reinforced.

4. The Quaternary system in the eastern part of Qaidam Basin is also a favorable region for deep strata biogenic gas. In this region, besides the discovery of the Sebei No 1 and No 2 and Tainan gas fields, a new understanding has also been gained recently concerning the gas-bearing properties of the southern slope zone and forecasts indicate that new discoveries may be made following additional work in the vast unexplored area of the southern slope zone.

5. Other regions like Tarim, Junggar, Bohai Bay, Chuxiong, and other basins have superior geological conditions for natural gas and there have been discoveries in all of them in natural gas exploration over the past several years. Moreover, reserves on a substantial scale have been found, so all of them are favorable regions to explore for gas in the near term.

#### **V. Primary Factors Restricting Development of the Natural Gas Industry**

Although China made major achievements in natural gas exploration during the Seventh 5-Year Plan, our rank in the world in natural gas reserves and output has fallen every year. Our investment structure also lags substantially average world investment levels. The oil/gas investment ratio is 2.4:1 in the Soviet Union and 2:1 in the United States, but only 10:1 in China. This shows that China's natural gas industry lags substantially behind average world levels both in terms of investments and in the amount of work and exploration results. The primary causes of this lag are:

##### **A. Incomplete management system, imperfect systems**

Although China's natural gas industry has a powerful resource foundation, vast realms of exploration, and a huge market for utilization, as well as a staff and technical equipment on a substantial scale, it got started late and has developed slowly, so even today we still lack a system adapted to development of China's natural gas industry and a complete management system, which are significantly restricting development of our natural gas industry.

The natural gas industry is composed of a series of procedures including exploration, extraction, transport, marketing, utilization, and so on. There are many things to attend to and much work involved, so there must be specialized departments to carry out unified planning and management before all items of work can be implemented. Because China's natural gas industry management system is

very incomplete, however, there is much work that is hard to implement. This is particularly true in combined natural gas exploration regions where there is no one to manage the series of policies and technologies adapted to the characteristics of natural gas or the exploration and development programs and plans, and so on, which has seriously affected the formulation of long-term plans and annual plans for each item of work.

##### **B. The principle of "combined development of oil and gas" has not been sufficiently implemented**

Because of the capital shortage at the present time, there is no special listing of natural gas investments, which, when added to the urgency of the tasks to increase petroleum production, has now formed a situation in which development is squeezing out exploration and petroleum is squeezing out natural gas. This is particularly true in combined natural gas exploration regions. The absence of personnel to manage natural gas exploration has resulted in reductions in natural gas reserves every year. In the Bohai Bay region, for example, the newly-added proven natural gas reserves fell from 37.9 percent of total newly-added proven natural gas reserves in China in 1986 to 10.5 percent in 1990.

##### **C. The price of natural gas has been too low for a long time, which has seriously affected development of the natural gas industry**

The price of natural gas in China is far lower than the world price of natural gas. In 1988, for example, the price was \$0.21 to \$0.30 per 1 m<sup>3</sup> of gas in the United States, \$0.19 to \$0.23 in West Germany, \$0.18 in Canada, \$0.25 in France, and \$0.24 to \$0.27 in Japan, but was just \$0.025 in China (calculated at \$1.00 = 5.2 yuan renminbi). Because the price in China has been too low and detached from the law of value for a long time, it has resulted in these negative consequences: 1) Exploration and development capital cannot be recovered and it is hard to expand reproduction; 2) The initiative of natural gas production personnel cannot be motivated, which has exacerbated the contradiction between supply and demand and severely affected development of the natural gas industry.

##### **D. Technical equipment is not adapted to the characteristics of natural gas**

There are many differences between the various work procedures in the natural gas industry and the work procedures for petroleum. Thus, there is a need for a set of equipment and technologies that are adapted to the characteristics of natural gas. Nevertheless, most of the equipment and technology in China in the areas of natural gas exploration, development, and so on was developed according to petroleum requirements, so it is very difficult to meet actual needs. Moreover, exploration often results in the negative consequences of gas strata leaking away and the plugging of contaminated gas strata. Thus, developing equipment and technology adapted to the requirements of natural gas exploration and development is one issue that should receive attention and awaits resolution in development of our natural gas industry.

We eagerly expect that the relevant departments will study the issues outlined above and adopt measures to resolve them. If these contradictions can be resolved, we are confident that our natural gas industry will inevitably achieve flourishing development.

This article was written on the basis of consulting the exploration and development achievements of all of China's oil and gas fields and we would like to offer our sincere thanks to the relevant comrades.

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#### Success Claimed in Remote Sensing of Oil and Gas Resources

926B0052C Beijing GUANGMING RIBAO in Chinese  
5 Jan 92 p 1

[Article by reporter Zhai Huisheng [5049 1920 3932]]

[Text] China is successfully applying air-borne remote sensing technology to direct prospecting for oil and gas: in known oil and gas areas of eastern Junggar Basin, remote sensing has achieved a [success] rate of 63.3 percent, and in 10 different kinds of areas where oil and gas were indicated, seven proved to have oil and gas after drilling; in the northern Tarim Basin, drill prospecting finds completely matched the findings made through remote sensing. The CAS academic committee member, expert Liu Guangding, appraised this fast, economic, and effective high technology to be the fulfillment of a long-cherished dream.

For many years seismic prospecting was the common method for finding oil and gas resources around the world. In the search for greater accuracy in prospecting, 16 research units of the CAS Remote Sensing Applied Research Institute and the Geology Institute of the Petroleum Prospecting Development Scientific Research Academy joined in the "oil and gas resources remote sensing direct prospecting technology" research task. Nearly 100 scientists and technicians worked for 4 years, and they successfully set up an oil and gas remote-sensing direct-prospecting apparatus for technical evaluation based on measuring micro-seepage

from oil and gas deposits. This eventually became the remote sensing direct prospecting applied technology, and the news of its advent was highly appreciated by oil and gas prospecting and production departments.

It is believed that in the Eighth 5-Year Plan further R&D on this world-class technology will be done, and it will be widely applied in oil and gas prospecting.

#### Qaidam Projects Go Into Operation

926B0053B Beijing RENMIN RIBAO in Chinese  
16 Jan 92 p 1

[Article by Hu Xisheng [5170 6007 3932]]

[Excerpts] [passage omitted] The large-scale development of the Qinghai oil fields is in full swing, and now in western Qaidam, construction of a major oil field for the production 1 million tons of crude oil annually has been completed; the 435 kilometer oil pipeline from Huatugou to Golmud was opened up last year, and has already transported over 1 million tons, which has been shipped over the Qinghai-Xizang railroad to the Lanzhou refinery; construction began in August of last year (1991) on the Golmud refinery, which will have an annual processing capacity of 1 million tons, for which investments have totalled 85 million yuan to date, and it will be completed and operational in 1994. [passage omitted]

#### Big Oil- and Gas-bearing Structures Found in Three Major Basins

926B0052B Guangzhou NANFANG RIBAO in Chinese  
15 Jan 92 p 3

[Text] Success stories of China's petroleum industry's developments in the west keep coming in; proven petroleum geological reserves in 1991 are topping those of 1990 by about 160 percent, as many oil and gas bearing structures keep turning up, further confirming that western China is taking over as the strategic area for petroleum resources.

Five high-output oil and gas wells have been initially confirmed in the Tarim Basin at Lunnan, Donghetang, Jilake, Sangtamu, and Jiefang Qudong, and high-output wells sprung up in the Tazhong and Yingshili areas as well.

Six oilfields were found in the Shanshan hills of the Turpan-Hami Basin where there are near-surface strata of good quality oil in rich reserves and the range of oil-bearing strata is still being expanded.

In the Junggar Basin, prospecting is moving from the rim toward the interior, and Cainan oil field was discovered in the Wucaiwan area of the Gobi where five exploratory wells turned up flows of industrial-grade oil.

## Status and Prospects of Nuclear Power Development in China

926B0059A Beijing WULI [PHYSICS] in Chinese  
Vol 20, No 11, Nov 91 pp 689-693

[Article by Guo Xingqu [6753 2502 3255] of China Institute of Nuclear Economics: "Status and Prospects of Nuclear Power Development in China"]

[Text] China's energy demand is increasing daily due to economic development and population growth. This paper discusses the status and prospects of the development of coal, oil, natural gas, hydroelectric power, solar energy, wind energy and nuclear energy in China from various viewpoints including resources, technology, economics and environmental impact. The conclusion is that nuclear power development is a fundamental way to solve China's energy, ecology and transportation problems.

At present, pressurized water reactors are the type of reactors for nuclear power. From this point on and for some time in the near future, nuclear power generation will be the main area of nuclear energy. In the next century, breeder reactors should become the primary type of reactors. In developing breeder reactors, we should follow the path of using metal fuel. Breeder reactors give us more time to wait for the arrival of nuclear fusion reactors.

After years of hesitation, China's nuclear power development finally took its first step. In the next 3 years, three nuclear power plants will be completed and put into operation. This marks a new chapter in the construction of energy sources in China. The development of nuclear power will have a bright future.

### I. Nuclear Power Development Is the Fundamental Solution to Our Energy Problem

Since the founding of the People's Republic of China, our energy industry has made a great deal of progress. From 1949 to 1990, our power generating capacity has risen from 1.85 million kW to 135 million kW, an increase of a factor of 72. Electricity generated per year increased 4,308 million kWh to 618,000 million kWh, an increase of a factor of 142.5. Coal production has risen from 32.4 million tons to 1,080 million tons, a 31.3-fold increase. Crude oil production has risen from 120,000 tons to 138,000,000 tons, an increase of a factor of 1149. Our overall energy production for commercial use has increased from 23.74 million tons of standard coal to 1,040 million tons of standard coal, a 43-fold increase.

Despite this outstanding accomplishment, our energy development is far behind our demand due to economic growth. The energy shortage is becoming more serious. Due to the energy shortage, our gross national product is reduced by at least 200 billion yuan. Power schedule becomes power rationing. Recently, due to a slowdown of the economy, the energy shortage is somewhat alleviated. However, this relief is temporary. In the 42 years prior to 1990, our total energy consumption for commercial use had increased to 1 billion tons of standard coal. Over the next 60 years, from 1990 to 2050, it is estimated that the total commercial energy consumption will rise to approximately 4 billion tons of

standard coal. Such a huge increase in our total energy demand will cause major changes in the energy structure.

### 1. The energy structure centered around coal brings us some serious problems.

Since 1949, coal has been the major source of energy. Approximately three quarters of the total energy consumed comes from coal. In the near future, coal will still be a major source of energy in China. However, it is impossible to maintain this situation on a long term basis.

According to the data reported at the 12th International Energy Conference, the amount of coal that is economical to mine is approximately 6.2 percent of the geological reserve. In recent years, although our estimated geological coal reserve continues to increase, the amount of coal that is economical to mine is under 200 billion tons of standard coal. Since it is fairly limited, it is difficult to exceed an annual production capacity of 2 billion tons of standard coal (approximately equivalent to 2.8 billion tons of raw coal). Hence, by 2050, the proportion of coal in our energy structure will decrease from 75 to 40 percent.

Our coal is mostly produced in Shanxi, Shaanxi and western Nei Monggol. However, our developed areas are concentrated in the east. Currently, coal occupies 40 percent of the freight capacity of the railroads. In the next century, as coal mines in the east are depleted, coal production bases will move into Shanxi, Shaanxi and Nei Monggol. Furthermore, coal consumption will increase sharply due to increased demand. By then, it will be more difficult to transport coal.

In addition to reserves and transportation, pollution of the environment is becoming a limiting factor for coal. From 1949 to 1990, although the cumulative coal consumption was only 12 billion tons of standard coal, the consequence is already very serious. Two to three hundred years ago, the air in Beijing was very clear. In 1671, Sun Chengze [1327 0015 3419] wrote that Beijing was visible from Baihua Shan 60 kilometers away. From Shi Shan at a distance of 40 kilometers, Beijing looked splendid in green and gold<sup>[1]</sup>. In 1745, Li Zongwan [0536 1350 8001] was able to count individual horses and pedestrians on the Lugou bridge 13 kilometers away from Guangan Gate in Beijing<sup>[2]</sup>.

Air pollution is already very serious in Beijing. In the 50's, there were on the average 45 smoggy days. In the 70's, there were 70 smoggy days. In the early 80's, there were close to 200 days<sup>[3]</sup>. In recent years, because of conversion to natural gas and centralized heat supply, the situation is improving. Nevertheless, although there are some local improvements, the overall environment is deteriorating. More than 20 million tons of soot and 15 million tons of sulfur dioxide are being discharged into the atmosphere in China each year. Approximately 70 percent of the soot and 90 percent of the sulfur dioxide come from burning coal. Coal is the major cause of environmental pollution, especially air pollution, in China. It is particularly worrisome that the cumulative consumption of coal in the next 42 years will be four times that consumed previously. This kind of high consumption will lead to very serious consequences.

If one still argues that soot and sulfur dioxide pollution can be treated, then consider the fact that the greenhouse effect caused by carbon dioxide released from burning fossil fuel cannot be reversed.

Since 1860, carbon dioxide concentration in the atmosphere has increased by approximately 25 percent. Approximately one-half of this increase came about after 1960. The amount of carbon dioxide discharged by China has increased from 1.63 percent of that discharged worldwide in 1950 to 11 percent in 1987. It still continues to rise.

In October 1985, the United Nations Environment Program, World Organization of Meteorology and the League of International Scientists jointly sponsored a special conference on carbon dioxide in Austria. It was pointed out in the meeting that the concentration of carbon dioxide in the atmosphere will double by 2030 compared to the level before industrialization. The temperature will rise by 1.5 - 4.5 °C and sea level will rise by 0.2 - 1.4 m. In May 1986, it was pointed out in a meeting sponsored by the Chinese Academy of Sciences on the effect of global warming on China's climate that the greenhouse effect will make draught-stricken areas in northern and northwestern China even drier. The desert will expand in size. In the rainy south, due to increased rainfall and changes in seasonal distribution, natural disasters will be more frequent.

It is also predicted that changes in climate worldwide in the next 50 years may surpass the widest range that the earth has experienced in the past thousand years. It will be very difficult for humans to adjust synchronously to such rapid changes. It was pointed out at the world atmosphere meeting held in Toronto in June 1988 that the final result of global warming is next only to a global nuclear war. A series of international meetings such as the one held in Toronto urged the world, as a first step, to reduce the discharge of carbon dioxide by 20 percent in 2005. By 2050, it should be reduced by 50 percent compared to the present level. Under this kind of situation, our rapid increase in carbon dioxide release will meet more and more international resistance.

In summary, because of resources, transportation and environmental protection, it will be impossible to use coal as a major energy source in the long term strategic planning of China's economy.

## **2. Energy problems can be solved by mainly relying on nuclear power.**

In 1990, petroleum was 19 percent of the primary energy source produced in China. Natural gas was only 2 percent. By 2000, it will be possible to maintain this ratio. It may even increase slightly. After 2000, the proportion of oil and gas in our energy structure will continue to decrease. Coal, oil and gas are not only energy resources but also critical raw materials for chemical plants. It would be extremely wasteful just to burn them.

China has the world's largest water resources. However, the per capita figure is low. By 2030, most water related energy resources will be fully developed. The energy is equivalent

to 200 to 300 million tons of standard coal per year. It does not play a major role in our energy structure.

Solar energy, because of its low energy density and wide fluctuation in availability with day and night, rain or shine, and seasonal changes, is very difficult to harness as a large-scale industrial energy source. The density of air is 1/800th that of water. Therefore, the diameter of a blade of a windmill is several hundred times that of a blade of a watermill of the same power. This makes windmill power generation more capital intensive. Wind energy not only has lower energy density but also varies in magnitude and direction from time to time. It is only appropriate in areas where the mean wind speed is high and other energy resources are in short supply. Presently, windmill generators provide less than 1/10,000th of the total power generating capacity. It will be hard to raise this ratio. The proportion of geothermal energy and tidal energy is also limited in the future in China.

Other than water, biomass is the only large-scale regenerable energy source. However, our forests have been cut down excessively, resulting in serious top soil loss. In the future, we should control total biomass consumption by developing efficient stoves and methane pools to improve utilization efficiency.

Since fossil fuels such as coal, oil and gas cannot carry the burden as our major energy resource, and regenerable energy source is only a supplement, we can only count on nuclear power to solve our energy problem [4,5].

## **3. Nuclear power is a safe, clean and economical industrial energy source.**

The main advantage of nuclear power is that it is highly concentrated. In fossil fuels such as coal, gas and oil, only one ten-billionth of the mass is converted into energy. However, in U-235 fission, approximately 9 ten-thousandths of the mass is converted to energy. The energy released from the complete fission of 1 g of U-235 is 2,800,000 times higher than the heat generated by 1 g of standard coal.

The direct effect of highly concentrated energy can cut down transportation load. A 1 MkW (million kilowatt) coal burning power plant needs over 2 million tons of coal per year. A 100 MkW nuclear power plant only needs a little over 30 tons of nuclear fuel per year. Because of its high safety standards, the capital required to build a nuclear power plant on a per kilowatt basis is 1.5 times that of a coal burning power plant. However, on the basis of heat generated, the cost of nuclear fuel is far cheaper than coal. This is why nuclear power is cheaper than coal generated power abroad.

80 percent of the radiation exposure comes from natural background radiation. Over 10 percent comes from medical treatment and diagnosis. Only less than 0.1 percent is due to commercial nuclear facilities such as power plants. After the Three Mile Island incident in 1979, a 1982 report released by a United Nations scientific committee on atomic radiation pointed out that if there is no improvement in nuclear

power plant technology and the total nuclear power generating capacity worldwide rises to 10 billion kW, which is equivalent to four times the total power plant capacity worldwide at present, the radiation caused by nuclear power plants will account for 1 percent of the natural background level.

The main advantage of nuclear power is that it does not discharge carbon dioxide, sulfur dioxide and nitrogen oxides. According to statistics released by the French environmental protection authority, the percentage of nuclear power increased from 24 percent to 70 percent between 1980 to 1986. During this period, the power generating capacity rose by 40 percent. However, the amount of sulfur dioxide discharged decreased by 56 percent, nitrogen oxides by 9 percent and soot by 36 percent. Air quality showed significant improvement.

In the history of nuclear power development, there have been two major incidents: Three Mile Island and Chernobyl. On 28 March 1979, radioactive materials leaked out of pressurized water reactor No. 2 at Three Mile Island due to a meltdown of nuclear fuel from loss of cooling water in the reactor. Because the reactor was equipped with a variety of safety systems, there were no casualties. The amount of I-131 released in this incident was 1,000 times lower than that released in a British military reactor incident in 1957 and four times lower than that released in an American military reactor incident in 1961. This incident, on the contrary, proved the safety of pressurized water reactors. After the incident, many improvements were made on pressurized water reactors.

On 26 April 1986, a graphite water-cooled reactor in Russia was in post-shutdown test. Because of violation of experimental procedures by the operators involved, reactor power rose abruptly, causing excessive steam buildup inside the reactor and eventually resulting in an explosion. It ignited the graphite inside the reactor. Nuclear and chemical reactions took place in an alternating manner to enlarge the scope of this incident over a long period of time. The amount of I-131 released in this incident is 400,000 times higher than that released at Three Mile Island. This type of reactor has poor resistance against such incidents and is no longer being developed in Russia. This kind of incident cannot possibly happen in pressurized water reactors. Hence, these two incidents cannot alter the conclusion that nuclear power is a safe and clean energy source.

## II. China's Nuclear Power Development Approach

Since 1950, China has built a complete nuclear industry system from uranium exploration, mining and nuclear fuel processing to reactor design, construction and operation. We exploded atomic and hydrogen bombs and launched nuclear submarines. This achievement is well recognized worldwide. Since the economic reform, our nuclear industry has turned toward serving our economy. According to expert opinion, by the middle of the next century our nuclear power development will experience three stages, i.e. supplement, composition and support.

In this century the primary objective is to grasp nuclear power technology. Upon completion of the three nuclear

power plants in the next 3 years, we will build several more plants until the end of this century. Thus, nuclear power will be a supplemental energy source. By early next century, nuclear power will become an important part of the energy structure along the east coast where energy is in short supply. By the middle of the next century, because of the development of fast neutron reactors, nuclear energy will be a critical supporting energy source in China.

### 1. Pressurized water reactor is the primary reactor at present.

In most reactors a chain of fission reactions is initiated by slowing down the fast neutrons released from the fission of uranium. Based on the moderator and coolant used, reactors can be classified as light water reactor, heavy water reactor and air-cooled reactor. Light water is ordinary water. It is used as a moderator and coolant in a reactor not only to slow down fast neutrons released from fission to thermal neutrons but also carries fission-produced heat out of the reactor to generate electricity. It also keeps the temperature of nuclear fuel within a normal range. A heavy water reactor usually uses heavy water as the moderator and coolant. Some heavy water reactors use heavy water as the moderator and light water as coolant. An air-cooled reactor uses graphite as its moderator and carbon dioxide or helium as the coolant.

In a light water reactor, if water does not boil inside the reactor it is called a pressurized water reactor. If water boils inside the reactor, it is called a boiling water reactor. Approximately 70 percent of the reactors installed are pressurized water reactors. It is the major reactor type at present and for the near future. Our nuclear submarines and all the nuclear power plants under construction are pressurized water reactors.

A pressurized water reactor is a high pressure boiler. The reactor core, made of uranium dioxide fuel, is over 3 m tall. It is placed in a 13 m tall, 4 m diameter pressure vessel. The pressure inside is maintained at over 150 atm. Cooling water at 300 °C is brought into the vessel from the bottom. After passing the core, it reaches 330 °C before entering the steam generator outside the pressure vessel. It converts the outflowing water in the secondary loop of the steam generator into high-temperature, high-pressure steam to turn a power generating steam turbine.

The moderating capability of light water is far higher than heavy water and graphite. Hence, a pressurized water reactor is compact in structure and lower in construction cost compared to a heavy water reactor or air-cooled reactor. In a pressurized water reactor, when the power surges and fuel temperature rises, its reactivity decreases to slow down the nuclear reaction and power. This is a negative feedback process. At Chernobyl, the feedback at low power is positive, which can easily make things worse during an incident. The Chernobyl power plant contained large amounts of graphite and zirconium, which made it easy for violent chemical reactions to start. A pressurized water reactor does not have any graphite and only has a small amount of zirconium. A Chernobyl-type of incident

cannot possibly happen in a pressurized water reactor. The technology associated with pressurized water reactors is already mature.

The 300,000 kW Qingshan nuclear power plant, which is scheduled for completion in 1991, is independently designed. Only key equipment such as the pressure vessel and main circulating pump is imported. Its completion will signify that China has a grasp on nuclear power technology. However, a pressurized water reactor must be over 1 MkW in size to be economically attractive. In order to have a handle on foreign advanced technology as expeditiously as possible, we are importing two 900,000 kW pressurized water reactors from France. They will be installed at the Guangdong nuclear power plant in 1992 and 1993, respectively.

The most urgent task is to convert nuclear power into domestic technology. Only if nuclear power can be developed domestically can the construction cost be lowered to an acceptable level to satisfy our huge demand for nuclear power. The key to domestic construction is the ability to design independently. Only with the ability to design independently can engineering management decisions be made independently and equipment be built domestically.

As far as capital investment is concerned, the nuclear reactor is only a small part of the entire power plant. Most of the investment is spent on power generators and wires and pipes. When we attempt to construct nuclear power plants domestically, the first step is to produce most of the routine and ancillary equipment domestically. China has a solid foundation for machine building. We must also organize ourselves to systematically develop key reactor equipment such as the pressure vessel. As for nuclear fuel, China already has the resources to produce it.

In order to achieve the goal of total independence, in 1987 the government approved the construction of two 600,000 kW pressurized water reactors at Qingshan after the 300,000 kW unit is completed. This project is a transition toward 1 MkW level pressurized water reactor and serves as a launching pad for total independence. The project is in the design and organization stage.

## 2. Fast reactor is the next step.

All the reactors described above, including pressurized water reactor, boiling water reactor, heavy water reactor and air-cooled reactor, are thermal neutron reactors. These reactors use a moderator to slow down fast neutrons produced by fission to produce thermal neutrons in order to enhance the probability of U-235 fission. The main disadvantage is that this type of reactor cannot breed nuclear fuel. It can only utilize a small part of the uranium. As an example, the fuel for a pressurized water reactor is 3 percent U-235 which is enriched from the natural level of 0.7 percent. The tailing of the enrichment process contains 0.25 percent uranium and it is considered depleted uranium. After 3 years of use in a pressurized water reactor, its U-235 content drops from 3 percent to 0.9 percent and it is called spent fuel. When it is in use, every U-235 nucleus consumed can convert approximately 0.5 U-238 nucleus into Pu-239,

a high-quality nuclear fuel. The fuel is being depleted while in use. Only 0.5 percent of the uranium is utilized in the entire process.

If a reactor does not use a moderator and directly uses the fast neutrons from fission to trigger more fission reactions, it is called a fast neutron reactor. In a fast neutron reactor, because fission reactions induced by fast neutrons generate more neutrons, and because parasitic capture of fast neutrons is low, with the exception that one neutron is required to continue the chain reaction and a small number of them is lost, approximately 1.2 to 1.6 neutrons can convert U-238 to Pu-239. Hence, more fuel is generated as it is being used. This phenomenon is the breeding of nuclear fuel.

The first reactor used for power generation was a fast reactor: the "Breeder 1" reactor at the Idaho National Reactor Test Center which was used to generate power in December 1951. After 40 years of development, breeder reactor technology has matured. The 1.2 MkW "super phoenix" breeder reactor which was first introduced in France in 1986 has been operating quite satisfactorily despite the incident of a leaky sodium storage container outside the reactor. At present, the construction cost of a breeder reactor is twice that of a pressurized water reactor. With rising nuclear fuel cost and construction of a large number of fast reactors, such reactors will grow very fast in the next century.

Because spent fuel of a fast reactor can be recycled after processing, and the processing does not have a very stringent impurity removal requirement, the amount of liquid waste generated is limited. Therefore, the amount of radioactive waste produced per kilowatt hour of power generated is much lower than that of a pressurized water reactor. Hence, it is considered by some as a cleaner energy source.

## 3. Metal fuel fast reactor is the major reactor in the next century.

There are two types of breeder reactors, i.e. oxide and metal. In an oxide breeder reactor, the fuel is a mixture of uranium dioxide and plutonium dioxide. Its breeding ratio, i.e. the amount of U-239 obtained after consuming one nucleus, is 1.2. Furthermore, oxide fuel can only be post-processed wet. The amount of time required for recycling outside the reactor is 2-3 years. Therefore, its doubling time, i.e. the amount of time to double the fuel, is over 15 years. A metal breeder reactor uses an alloy of uranium and plutonium and zirconium as its fuel. The breeding ratio is 1.6. Because it can be post-processed dry, it is simple to do and can be done on site. Hence, its doubling time is shortened to 6 years. In order to meet the huge demand for nuclear power in the next century, it will be the major type of reactor in China.

Fast reactors can effectively utilize U-238, the form that 99.3 percent of natural uranium is in, and convert it into Pu-239. This makes low grade uranium ores attractive to mine. A fast reactor can more effectively utilize uranium by tens of thousands of times compared to a pressurized water reactor. A breeder reactor gives us more time to wait for a fusion reactor to arrive.

#### 4. The use of fusion energy cannot be rushed.

Although large-scale fusion was realized in 1952 by way of atomic weapons, controlled fusion is far more difficult to achieve. After decades of effort, there is a possibility that fusion ignition may come true in the last 10 years of this century. Nevertheless, to have beneficial energy output and to compete with other energy sources controlled fusion will have to wait until the middle of the next century.

As early as 1953, P. F. Powell presented the concept of a hybrid fission-fusion reactor. He suggested placing a U-238 or Th-232 breeder layer outside the fusion reactor. The fusion-produced high energy neutrons can convert U-238 and Th-232 into Pu-239 and U-233, respectively. Theoretical calculation and experimental work proved that one fusion-produced neutron not only can induce fission to release a great deal of energy but also can produce 5 Pu-239 nuclei. Some experts believe that such a hybrid reactor is a bridge between fission and fusion [6]. However, other experts believe that it will be difficult to build a hybrid reactor because of the radioactive fission layer which makes maintenance and repair more difficult than a pure fusion reactor. For this reason, although there have been many plans to build hybrid reactors since 1953, none of them are being designed yet.

Since 1950, many physicists have been overly optimistic about the prospect of fusion as a solution to the energy problem. Nevertheless, our experience in the past several decades indicates that it is unrealistic to count on fusion to solve the energy problem, at least for the next century. The energy problem of the next century will be solved mainly by breeder reactors.

Economic growth and population explosion make our energy needs more pressing day by day. Our main energy source is coal. It is closely tied to energy shortage, power shortage, pollution and excessive transportation load. Large-scale nuclear power development is a fundamental solution. From the end of this century to early next century, pressurized water reactors will be the main focus of nuclear power in China. It will be a supplement. In the next century, after metal breeder reactors are fully developed, nuclear power will play a major part in our energy structure.

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#### Qinshan Said To Be Operating Without a Hitch 926B0065B Beijing RENMIN RIBAO in Chinese 24 Feb 92 p 1

[Article by reporter Zhuo Peirong [0587 1014 2837]: "Operational Debugging of Qinshan Nuclear Power Plant Going Smoothly, Daya Bay Nuclear Power Plant No 1 Generator Conventional Island Equipment Installation Basically Completed"]

[Text] With the arrival of the new year, joyous news is arriving from several work sites in China's nuclear power construction. Operational debugging work is proceeding smoothly at Qinshan Nuclear Power Plant, which not long ago was successfully tested in connection to the grid and power generation, and the power is now being raised according to the predetermined procedures. Equipment installation at the conventional island of the No 1 generator at Daya Bay Nuclear Power Plant is basically completed. The basic design for the second phase project at Qinshan Nuclear Power Plant will be completed soon and the relevant projects to attack key S&T problems have been arranged and assigned.

Officials in the China Nuclear Industry Corporation assessed these achievements as an indication that China's work on the peaceful uses of nuclear energy has entered an entirely new stage.

Through the arduous efforts of builders over 81 months, the Qinshan 300MW nuclear power plant in Zhejiang, the first nuclear power plant designed and built by China itself, was successfully tested in connection to the grid and power generation for the first time on 15 December 1991. The 140 predetermined operational debugging and testing projects are now being carried out meticulously and the operating power has now been raised without a hitch to 30 percent. Full power operation may be attained in June or July.

The two 900MW nuclear power plants at Daya Bay in Guangdong, which are being built mainly using equipment imported from foreign countries, has now entered the key stage of the project.

The two 600MW generators for the second phase at Qinshan Nuclear Power Plant have been included among key state projects for the Eighth 5-Year Plan. The feasibility research report has now passed debate and the basic design is nearing completion. Production of several large pieces of equipment has now been arranged at specified sites. The construction design and preparatory engineering will begin during 1992 and the related scientific research project to attack key problems will be fully underway.